Virulence evolution in a protozoan parasite (*Ophryocystis elektroscirrhra*) of monarch butterflies (*Danaus plexippus*)

Followed by:

10 questions to ask your biology teacher about evolution
Darwin's 4 postulates

- Individuals vary
- Some of the variation among individuals is heritable
- Individuals with favorable variations survive and reproduce: natural selection
- Evolution: inherited change in a group of organisms over time

Every population has potential to increase exponentially

Very few populations do increase exponentially

Resources are limited

There is a struggle for existence: not all individuals survive and reproduce
Galapagos finches

Medium ground finch
Geospiza fortis

Daphne major
1. There is variation

Variation in beak depth in 1976

Source: Freeman & Herron Evolutionary Analysis 2007
2. Some of the variation is heritable

Source: Freeman & Herron Evolutionary Analysis 2007
3. Not all birds survive and reproduce

Source: Freeman & Herron Evolutionary Analysis 2007
4. Birds with deeper bills survived better than those with shallower beaks

Before drought

1976 all Daphne birds
N = 751

After drought

1978 survivors
N = 90

Source: Freeman & Herron Evolutionary Analysis 2007
Result: the population of finches evolved

Finches hatched in 1976, the year before the drought

Finches hatched in 1978, the year after the drought

Source: Freeman & Herron Evolutionary Analysis 2007
Parasites: worms, protozoans, bacteria, fungi, viruses

Virulence: parasite-induced reduction of host fitness
Parasites harm their hosts
Why do parasites harm their hosts?

Hypotheses:

1. **Coincidental evolution**
   Virulence is not target of selection itself, but an accidental by-product of selection on other traits.
   Example: tetanus caused by *Claustridium tetaneae*

2. **Short-sighted evolution**
   Virulence results from rapid selection for growth in tissues from which pathogen cannot transmit.
   Examples: poliovirus; *E. coli* bladder infections

3. **Trade-off hypothesis**
   Virulence results as a by-product from natural selection on parasite transmissibility.
   Examples: myxomatosis; monarch butterfly parasites
Parasite fitness is a trade-off between transmission and virulence.

Why do parasites cause harm?

Parasite exploitation

Transmission stages

Resulting fitness

Mortality

Parasite exploitation
What we study

1. Can virulence evolve as a consequence of natural selection on parasite transmission?
   - virulence-transmission trade-offs
   - genetic and geographic variation

2. Do ecological factors affect virulence?
   - larval host plants

Can we then predict how ecology shapes virulence evolution?
Asclepias spp.

Ophryocystis elektroscirrha
Monarchs in the lab
Virulence-transmission trade-offs: *virulence and transmission*
Virulence-transmission trade-offs: \textit{parasite fitness as a function of} \( p \)

\begin{align*}
\text{Generation:} & \quad t \\
\text{Generation:} & \quad t+1
\end{align*}

\begin{align*}
E(p) & \times M(p) \\
& \times T(p) \\
& \times I(d(p))
\end{align*}
Virulence-transmission trade-offs: *parasite fitness maximal at intermediate p*
Genetic and geographic variation: *natural clones around optimum*

De Roode, Yates & Altizer (2008) *PNAS*
• Greater spore load → greater virulence and transmission
• Highest parasite fitness at intermediate spore load
• Virulence has genetic basis
• Natural spore loads near predicted optimum

→ Suggests natural selection on transmission can result in virulence evolution
Ten questions to ask your biology teacher about evolution.

1. ORIGIN OF LIFE. Why do textbooks claim that the 1953 Miller-Urey experiment shows how life's building blocks may have formed on the early Earth -- when conditions on the early Earth were probably nothing like those used in the experiment, and the origin of life remains a mystery?

2. DARWIN'S TREE OF LIFE. Why don't textbooks discuss the "Cambrian explosion," in which all major animal groups appear together in the fossil record fully formed instead of branching from a common ancestor -- thus contradicting the evolutionary tree of life?

3. HOMOLOGY. Why do textbooks define homology as similarity due to common ancestry, then claim that it is evidence for common ancestry -- a circular argument masquerading as scientific evidence?

4. VERTEBRATE EMBRYOS. Why do textbooks use drawings of similarities in vertebrate embryos as evidence for their common ancestry -- even though biologists have known for over a century
1. ORIGIN OF LIFE

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“There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.”


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*Charles Darwin (1872) The Origin of Species, 6th ed.*
1. ORIGIN OF LIFE

This experimental set-up assumed that life originated on the ocean-atmosphere interface.

Miller and Urey 1952
2. DARWIN’s TREE OF LIFE

Why don't textbooks discuss the "Cambrian explosion," in which all major animal groups appear together in the fossil record fully formed instead of branching from a common ancestor -- thus contradicting the evolutionary tree of life?

The Cambrian explosion: ~550 mya
Oxygen levels rose dramatically
2. DARWIN’s TREE OF LIFE

Cambrian | Ordovician | Silurian | Devonian | Carboniferous | Mississippian | Pennsylvanian | Permian
---|---|---|---|---|---|---|---
543 mya | 495 | 439 | 408.5 | 353.7 | 290 | 251

First shelled organisms | First bryozoans (newest animal phylum) | First land plants | First winged insects | First mammal-like reptiles
Arthropods diversify | First chordates | First fish with jaws | First tetrapods (amphibians) | First basidiomycete fungi
First vertebrates (jawless fishes) | First zygomycete fungi | First insects | First ferns, vascular plants | First vessels in plants
First bony fish | First bony fish | First seed plants | First reptiles | First vessels in plants
First dinosaurs | First mammals | First bird (Archeopteryx) | First placental mammals | First flowering plants
First apes | Oldest pollen from composite family plants | Earliest hominids
First horses | First apes | Oldest pollen from composite family plants | Earliest hominids
Paleocene | Eocene | Oligocene | Miocene | Pliocene
3. HOMOLOGY

Why do textbooks define homology as similarity due to common ancestry, then claim that it is evidence for common ancestry -- a circular argument masquerading as scientific evidence?

“What could be more curious than that the hand of man, formed for grasping, that of the mole for digging, the leg of a horse, the paddle of a porpoise, and the wing of a bat, should all be constructed on the same pattern, and should include the same bones, in the same relative positions.”

Charles Darwin, The Origin of Species

Homology: traits are homologous when their underlying structure or development is similar, even if their function is completely different. Such similarities are most easily interpreted through common ancestry.
3. HOMOLOGY

Gene: contains data and replicates

Messenger RNA: data translated by enzymes

Proteins: provides meaning

The universal genetic code

DNA:
- C
- A
- A
- C
- G
- T
- C
- C
- G
- A
- C
- A
- A
- G
- T

mRNA:
- G
- U
- U
- G
- C
- A
- G
- C
- U
- G
- U
- U
- C
- A

Protein:
- Valine
- Alanine
- Glycine
- Cysteine
- Serine
Why do textbooks use drawings of similarities in vertebrate embryos as evidence for their common ancestry -- even though biologists have known for over a century that vertebrate embryos are not most similar in their early stages, and the drawings are faked?
4. VERTEBRATE EMBRYOS

Fig. 1. Upper figure human embryo, from Ecker. Lower figure that of a deg. from Bischoff.

- a. Fore-brain, cerebral hemispheres, etc.
- b. Mid-brain, corpora quadrigemina
- c. Hind-brain, cerebellum, medulla oblongata
- d. Eye
- e. Ear
- f. First visceral arch
- g. Second visceral arch
- H. Vertebral column and muscles in process of development
- i. Anterior extremities
- j. Posterior extremities
- K. Tail or os coccygis

Source: Darwin 1871 The Descent of Man
4. VERTEBRATE EMBRYOS

http://www.channel4.com/science/microsites/A/animals_in_the_womb/gallery_2_gallery.html
5. ARCHAEOPTERYX

Why do textbooks portray this fossil as the missing link between dinosaurs and modern birds -- even though modern birds are probably not descended from it, and its supposed ancestors do not appear until millions of years after it?

_Archaeopteryx_ is not a missing link, but a _transitional form_, a fossil that presents evidence that a form intermediate between birds and dinosaurs once existed.
5. ARCHAEOPTERYX

Dromaeosaurus

Caudipteryx

Sinosauropteryx
6. PEPPERED MOTHS

Why do textbooks use pictures of peppered moths camouflaged on tree trunks as evidence for natural selection -- when biologists have known since the 1980s that the moths don't normally rest on tree trunks, and all the pictures have been staged?

*Biston betularia*

Where peppered moths rest by day (2001-2006)

<table>
<thead>
<tr>
<th></th>
<th>Trunks</th>
<th>Branches</th>
<th>Twigs</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>28</td>
<td>40</td>
<td>11</td>
<td>79</td>
</tr>
<tr>
<td>Females</td>
<td>20</td>
<td>30</td>
<td>6</td>
<td>56</td>
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<tr>
<td>Totals</td>
<td>48</td>
<td>70</td>
<td>17</td>
<td>135</td>
</tr>
</tbody>
</table>

*Source: Majerus, unpublished results*
6. PEPPERED MOTHS

Genotype

cc  typica
insularia
Cc  carbonaria
CC

European

North-American

Source: Grant 2005 Encyclopedia of Life Sciences
6. PEPPERED MOTHS

Manchester

1730

1860

1954

Sources: Rudge 2006, Kettlewell 1973, Ridley 2008
6. PEPPERED MOTHS

Source: Grant et al 1996 Journal of Heredity 87, 351
7. DARWIN’S FINCHES

Why do textbooks claim that beak changes in Galapagos finches during a severe drought can explain the origin of species by natural selection -- even though the changes were reversed after the drought ended, and no net evolution occurred?
8. MUTANT FRUIT FLIES

Why do textbooks use fruit flies with an extra pair of wings as evidence that DNA mutations can supply raw materials for evolution -- even though the extra wings have no muscles and these disabled mutants cannot survive outside the laboratory?
9. HUMAN ORIGINS

Why are artists' drawings of ape-like humans used to justify materialistic claims that we are just animals and our existence is a mere accident -- when fossil experts cannot even agree on who our supposed ancestors were or what they looked like?
9. HUMAN ORIGINS

Figure 26-6: Evolutionary Analysis, p. 4
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9. HUMAN ORIGINS
10. EVOLUTION A FACT?

Why are we told that Darwin's theory of evolution is a scientific fact -- even though many of its claims are based on misrepresentations of the facts?

What is meant with Darwin’s theory?
- Descent with modification?
- Natural selection?
- Humans are apes?

If any of these 3, then the answer is a resounding “yes”.
Population evolves resistance within a patient

Source: Freeman & Herron Evolutionary Analysis 2007