Crafting and Testing Adaptive Hypotheses

36-149 The Tree of Life

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Review

The theories of common descent and natural selection play different roles within the theory of evolution.

Common Descent explains the unity of life.

Natural Selection explains the diversity of life.

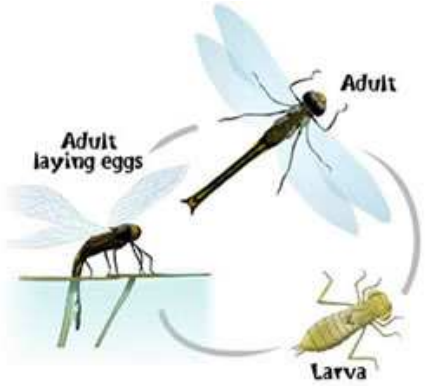
Darwin based his idea on a logical and an analogical argument. We also saw numerous examples of natural selection observed in the lab and in the wild.

Adaptations

- An *adaptation* (or adaptive trait) is any heritable features (or set of associated features) whose presence increases an organism's fitness in a given environment.
- Nonadaptive Traits
  - Learned behaviors (e.g., writing, the two-legged goat)
  - Outcome of genetic drift
  - Correlated features (esp. during development, e.g., male nipple)
  - Historical structures (e.g., human throat arrangement)
- All adaptations are produced by natural selection, but not all products of natural selection are adaptations.
- Testing adaptive hypotheses: How can we tell if a trait represents an adaptation?

Examples of Adaptations

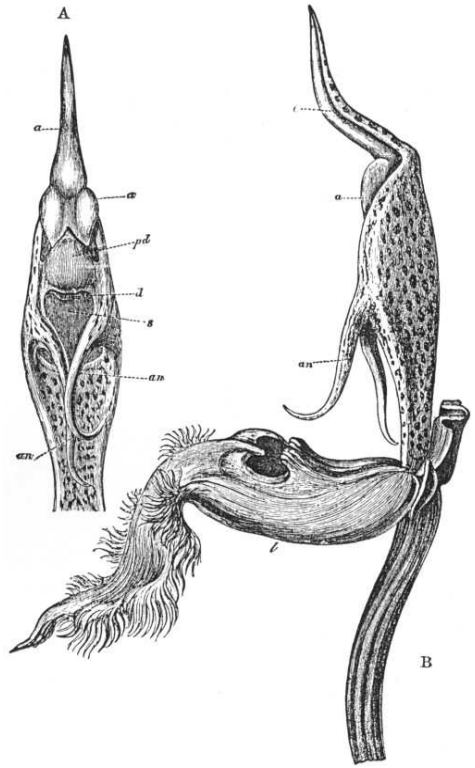
- Metamorphosis in insects

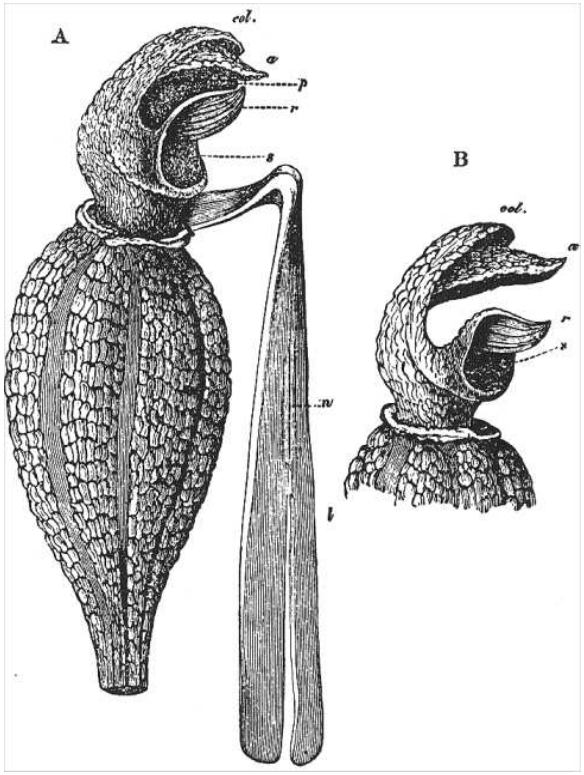


- Cactus spines

Examples of Adaptations (cont'd)

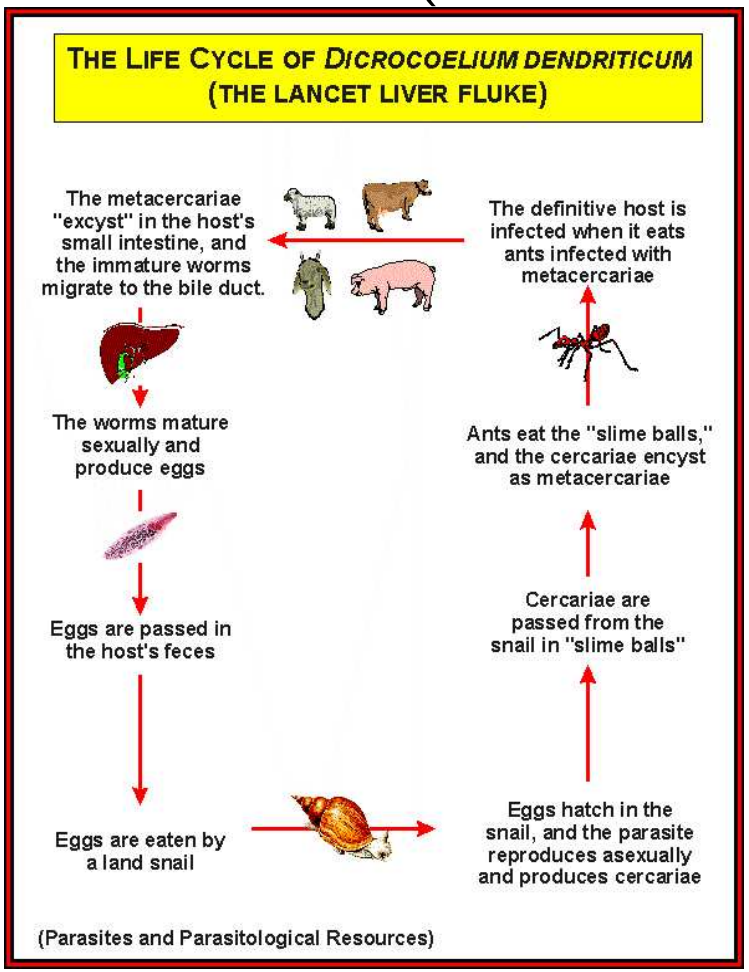
- Orchids





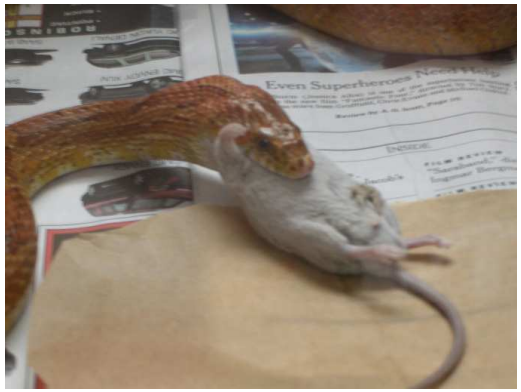
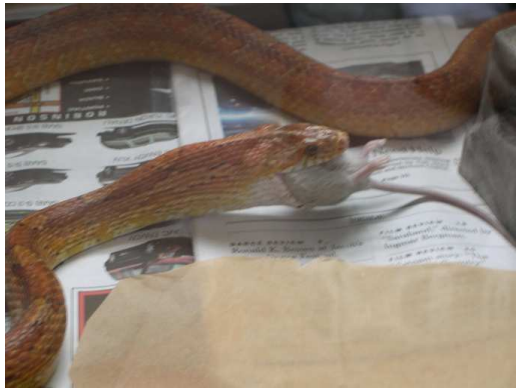
Examples of Adaptations (cont'd)

- The Lancet Fluke (*Dicrocoelium dendriticum*)



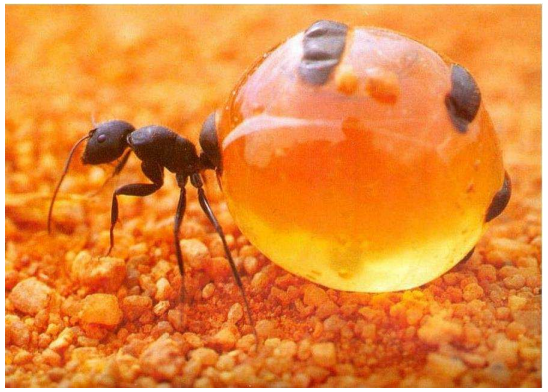
Examples of Adaptations (cont'd)

- Snake skulls


Examples of Adaptations (cont'd)

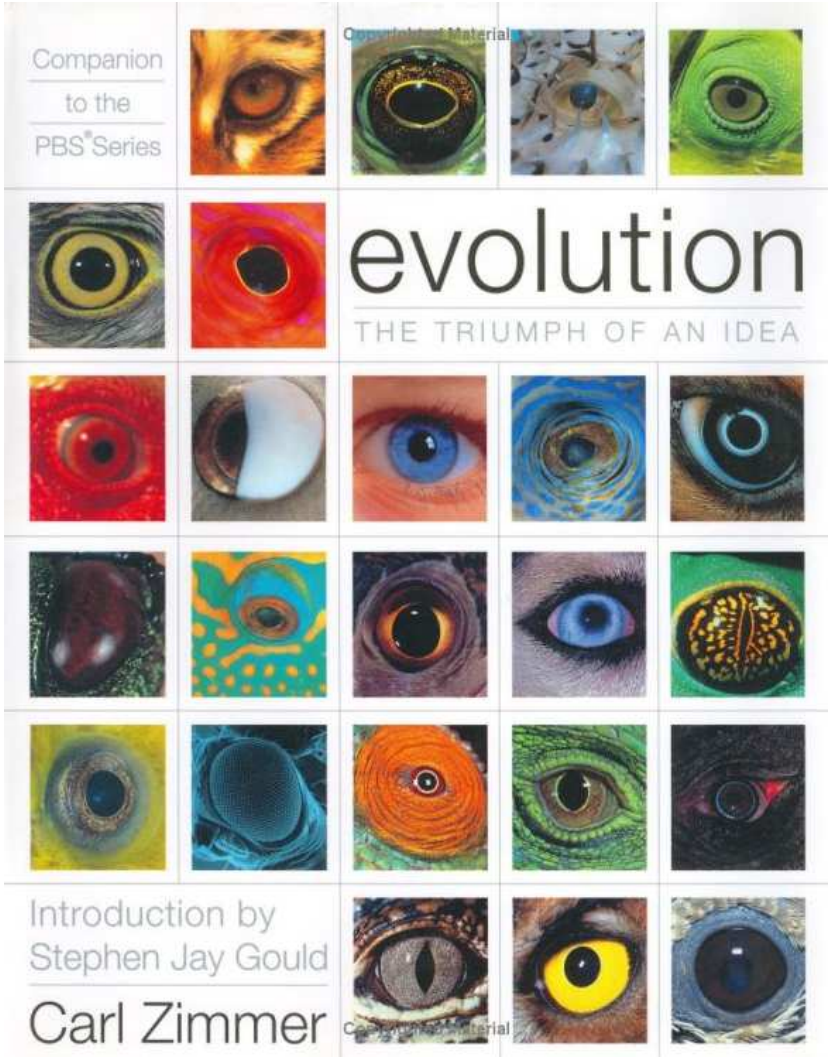
- Ants
  - Honeypot ants (*Myrmecosystus*)
  - *Zacryptocerus varians*, a twig-nesting species
  - Leaf cutter ants (*Atta*, *Acromyrmex*)
  - Weaver Ants (*Oecophylla*)
  - Aphid Herders (many)



- Mimicry

Examples of Adaptations (cont'd)

The Eye



A Few Tricks of the Trade

Natural selection has been observed, as our earlier examples show, but are these kind of changes really sufficient to produce the startling, complex adaptations we've seen?

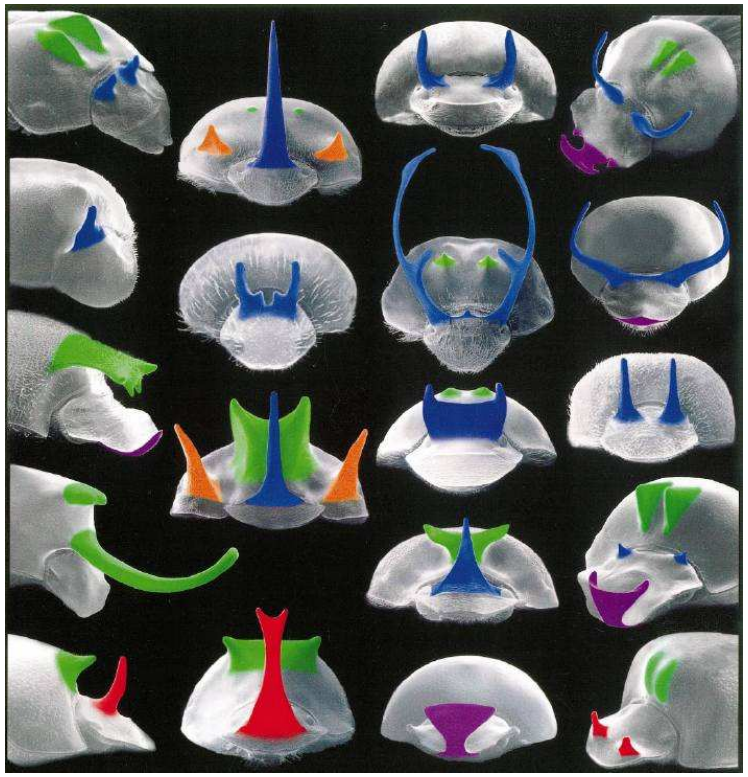
How can natural selection produce complex traits?

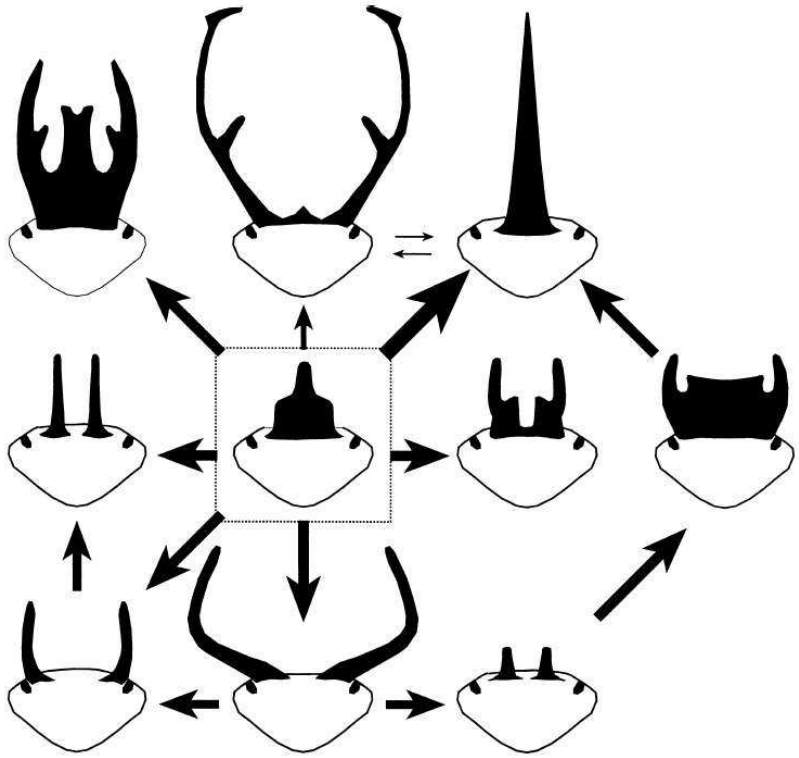
There are many ways, but here are a few.

A Few Tricks of the Trade (cont'd)

1. Changing the dimensions of existing traits

Example: Dung Beetle Horns (Douglas Emlen, University of Montana)



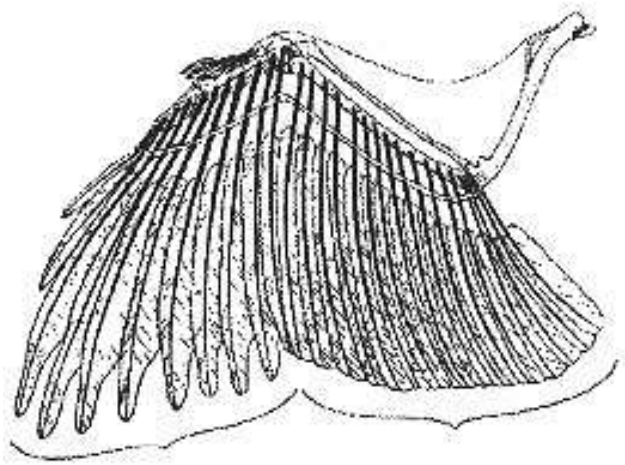


A Few Tricks of the Trade (cont'd)

2. Co-opting existing structures for new uses (Exaptation)

Example: wings

What use is half a wing? The assumption of functional continuity.



A Few Tricks of the Trade (cont'd)

3. Elaborating on redundant functions

Example: gills and lungs in lungfish

Reasoning about adaptations

Things to keep in mind when discussing adaptations:

1. Adaptations are fundamentally tied to a particular environmental context.
2. Adaptations are constrained by the history and biology of the organisms possessing them.
3. The benefits conferred by an adaptation can only be evaluated in relative, not absolute terms.
4. We cannot assume that an adaptation evolved through natural selection for its current function or even for a single function.

Adaptive Hypotheses

How can we tell if a trait represents an adaptation?

Two types of hypotheses:

1. Trait X is an adaptation.
2. Trait X is an adaptation that evolved because Y.

A few questions to ask about trait X for hypotheses of the first type:

- Is the trait the product of genetic variation (and thus heritable)?
- Does the trait influence an organism's survival or reproductive success?
- How does that influence operate in nature? What are the selective pressures operating in the particular environment?
- Relative to the other possible factors influencing fitness in the given environment, does that trait have a significant impact on survival or reproduction in natural populations?

Adaptive Hypotheses (cont'd)

A few additional questions to ask about trait X for hypotheses of the second type:

- What is the phlylogenetic history of the trait?
- How does the trait develop?
- What functions might the trait serve for the organism? How does this work? How does this depend on the environment?
- How is the trait's expression influenced by the environment?
- Having answered these questions, are the answers consistent with the hypothesis?

Methods for Studying Adaptation

- Modeling
- Considerations of Design and Complexity
- Experiment
- Comparative Method
- Building Phylogenetic Trees

Enjoy the "Just-So Story", but beware the "Just-So Story"!

Example: The Eye

Is the trait the product of genetic variation (and thus heritable)?

Yes. Why?

Does the trait influence an organism's survival or reproductive success?

Yes. How?

How does that influence operate in nature? What are the selective pressures operating in the particular environment?

To answer this question, we'd have to consider the various types of eyes and the environments in which they operate.

The basic benefits are: detecting predators, detecting and tracking prey, finding food, finding protection, identifying members of the same species, finding mates.

Species without eyes or that don't depend on them offer useful comparisons.

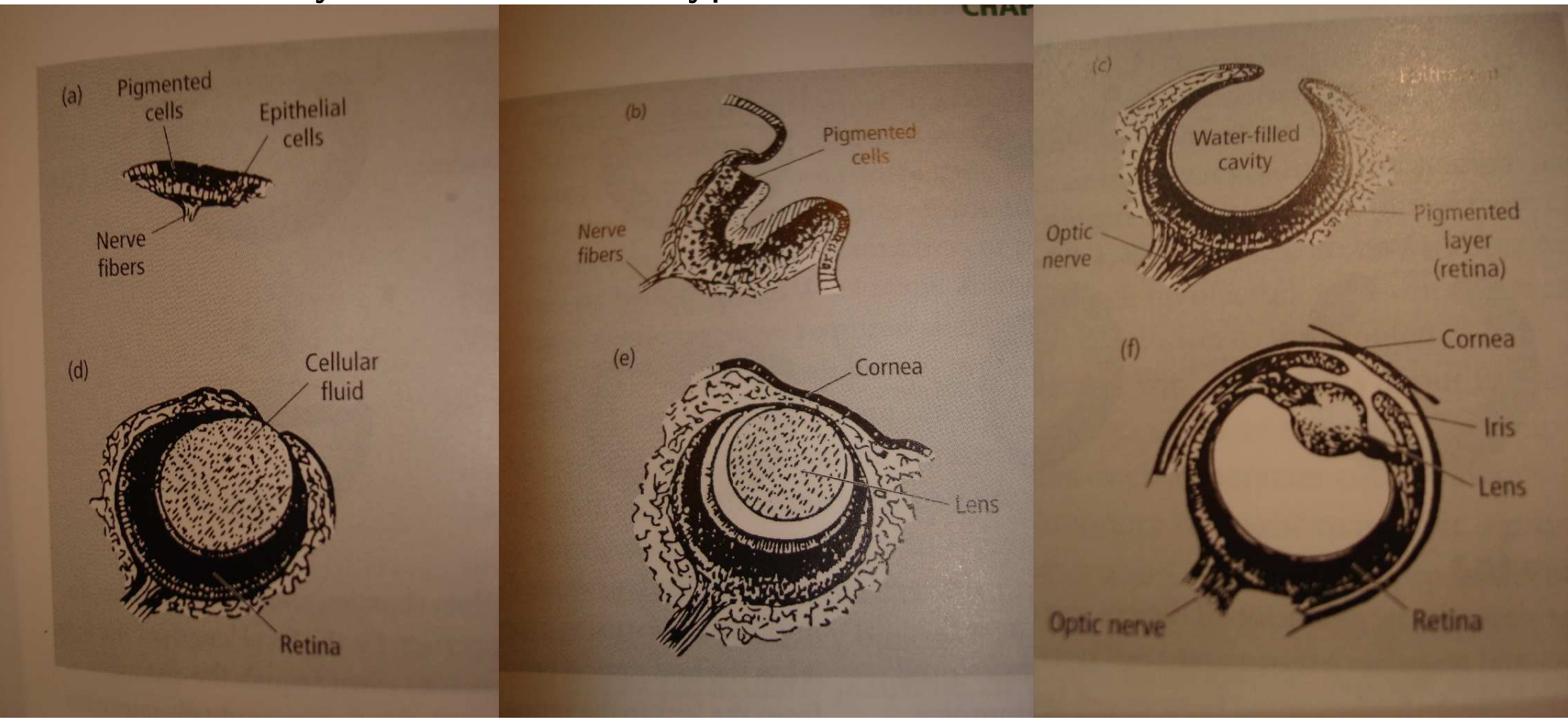
The Eye (cont'd)

Relative to the other possible factors influencing fitness in the given environment, does that trait have a significant impact on survival or reproduction in natural populations?

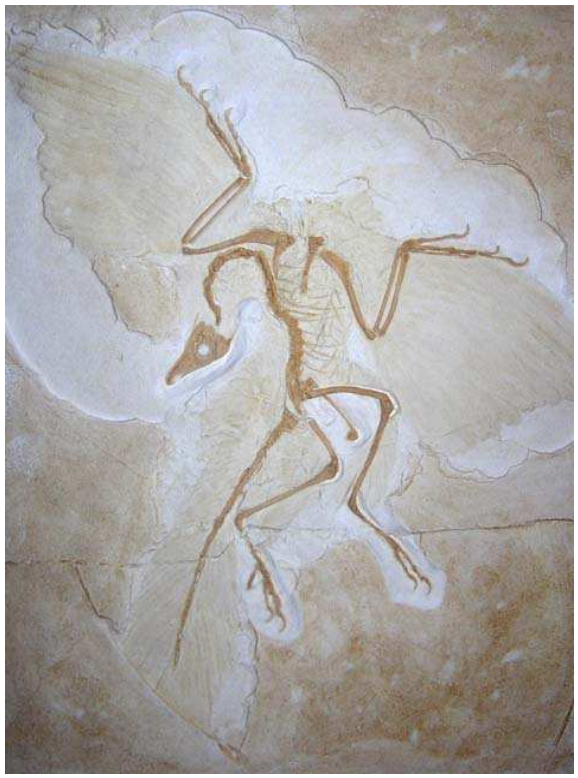
What experiments might we carry out to test this?

The Eye (cont'd)

How did eyes evolve? One hypothesis:



Example: Feathers



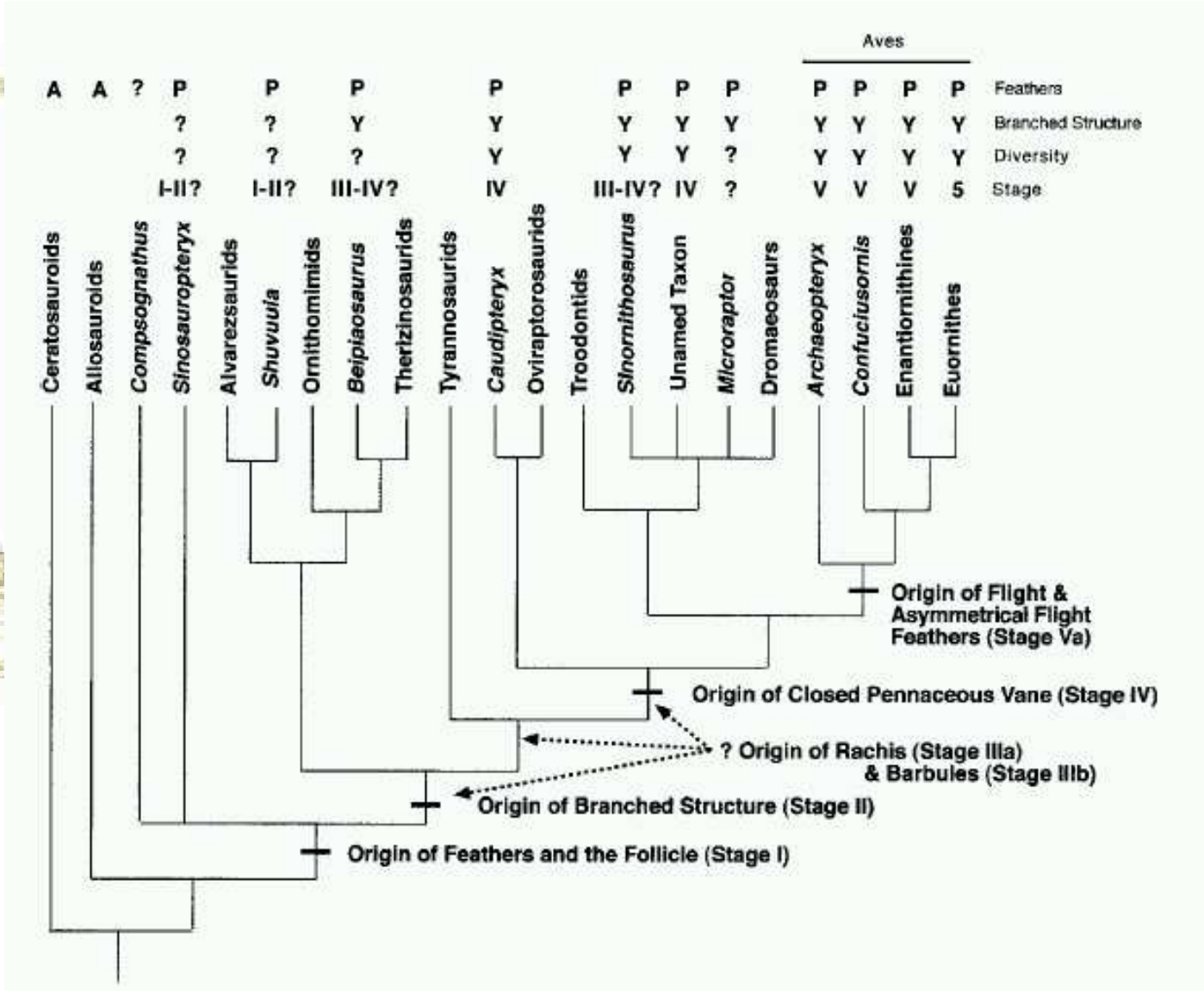
Feathers are the most complex covering appendages found among vertebrates.

They have a complex branching structure, a unique growth mechanism, and they potentially serve many functions.

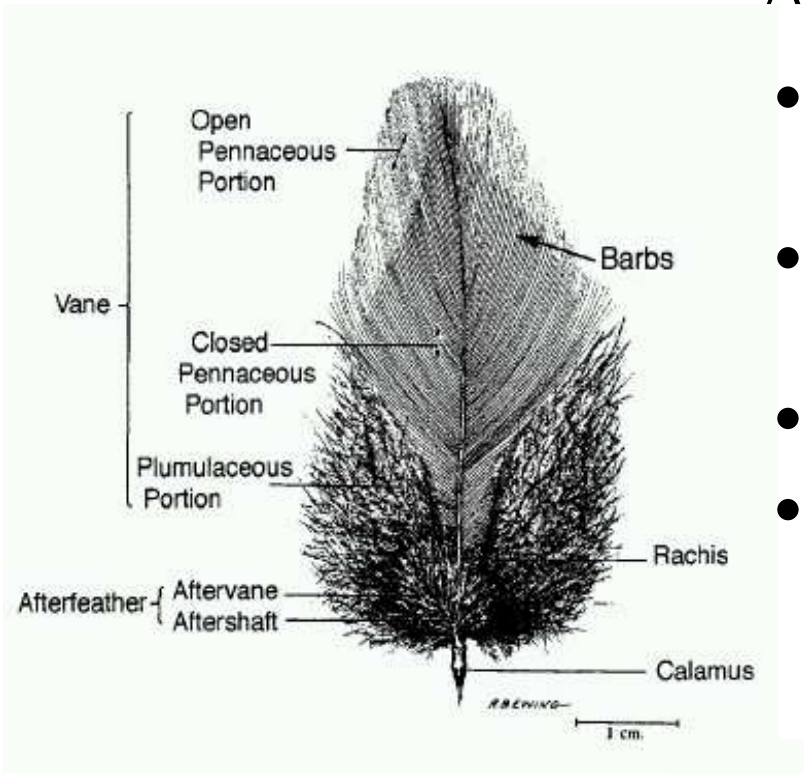
The evolutionary origin of feathers has long been a major question.

Feathers (cont'd)

Recent finds of feathered dinosaurs have made the question even more interesting.

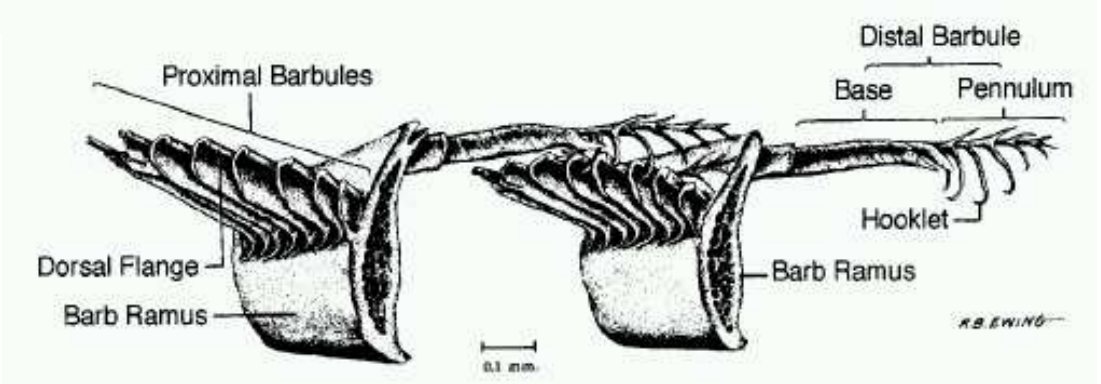


Feathers (cont'd)



Approaches to studying the evolution of feathers:

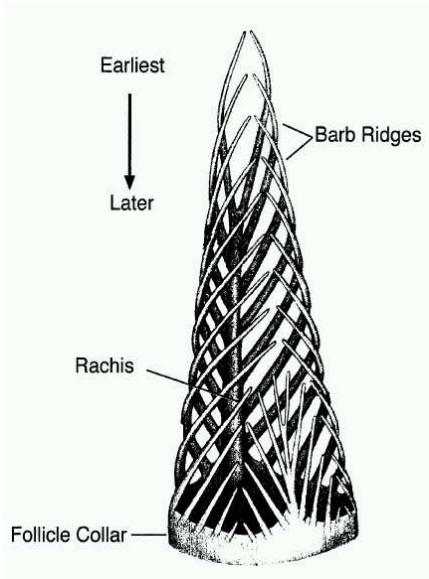
- Identify "primitive" morphology from existant birds
- Consider possible prior structures (e.g., scales) from which feathers developed
- Functional (adaptive) hypotheses
- Developmental Biology



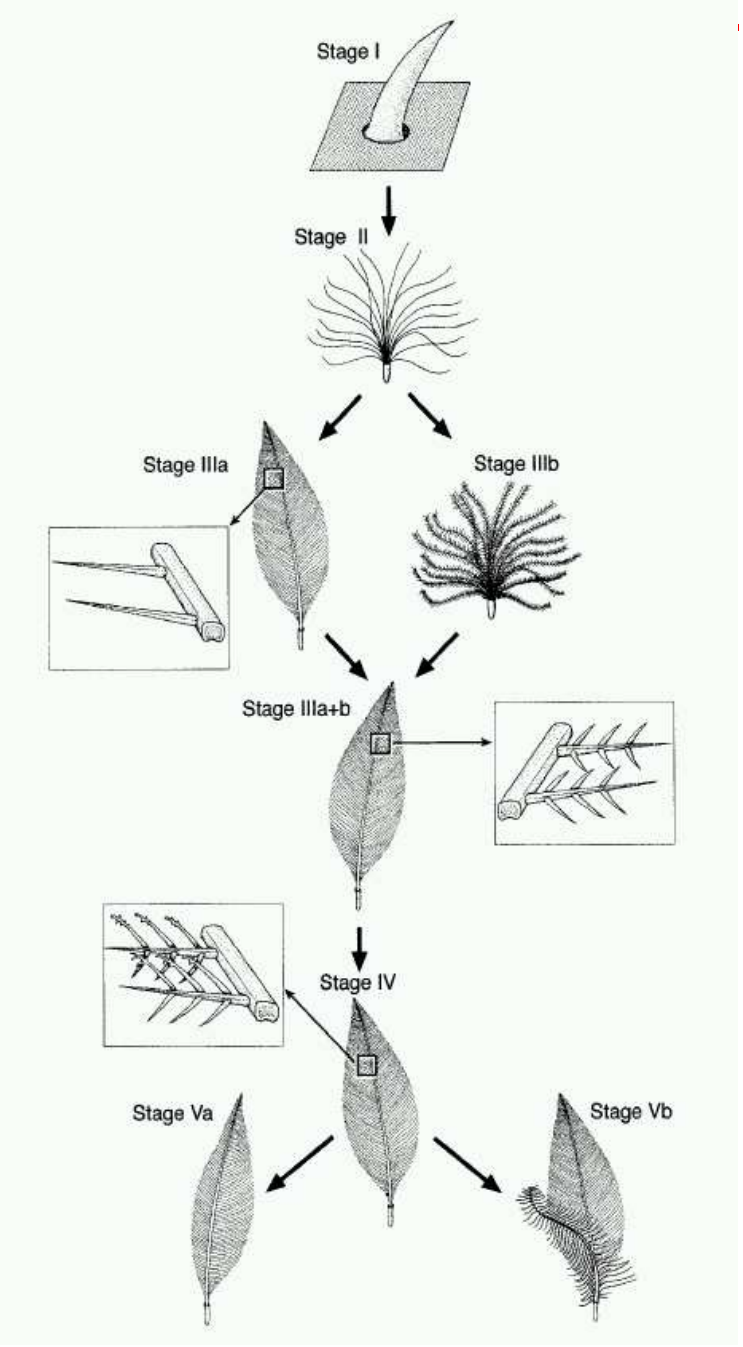
Feathers (cont'd)

Functional hypotheses of feather origins:

- Flight
- Thermal insulation
- Solar shielding
- Water repellance
- Communication and Sexual Display
- Defense

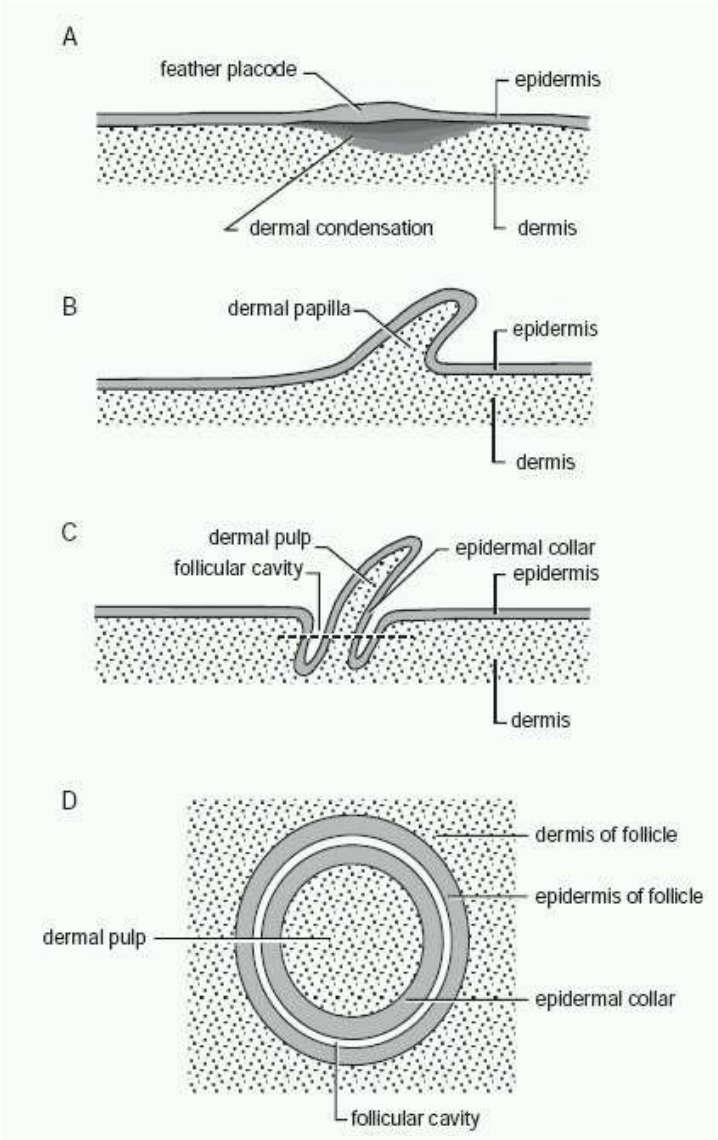


Feathers (cont'd)



Developmental studies lead to a different theory of feather origins.

Supported by genetic studies of body-plan toolkit genes.



Case Studies: Adaptation and Complex Structure

1. Fear of Spiders
2. *Stegosaurus* plates
3. Worker Bees
4. Autumn Leaves
5. Orgasm in humans
6. Bipedality in humans

Fear of Spiders

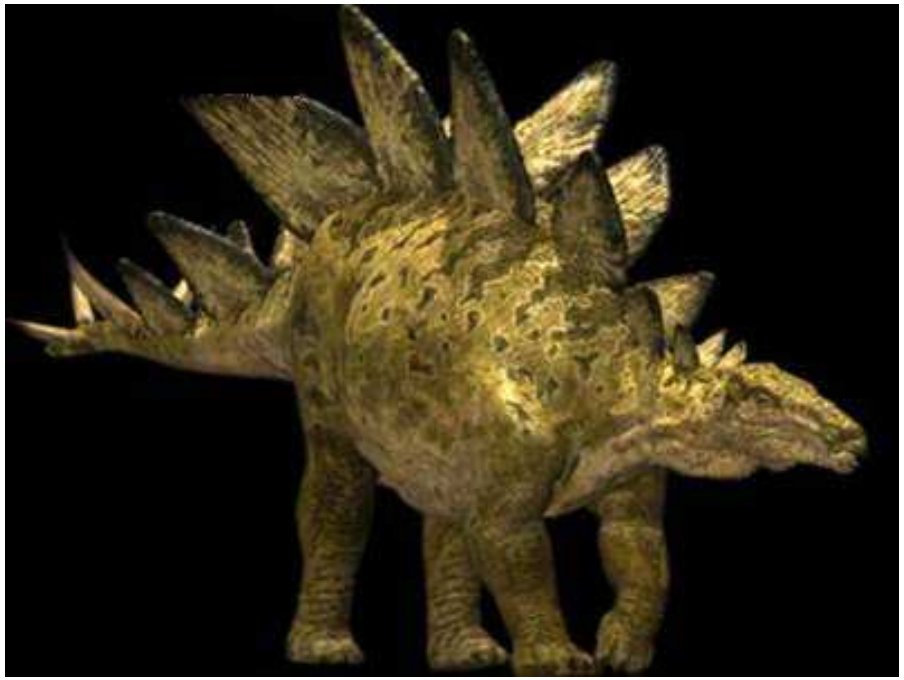
Observation: Across ages and cultures, many (most?) people exhibit a strong and immediate fear of spiders (and snakes).

Questions: Why? Is this an evolutionary adaptation? How do we test this hypothesis? What would serve as evidence or counter-evidence?

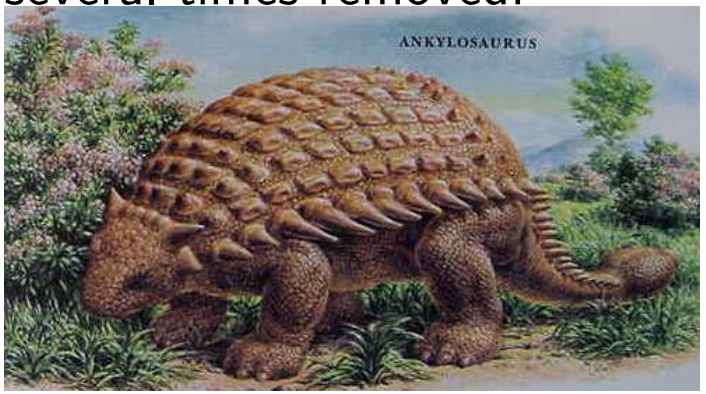
Stegosaurus Plates

Observation: Dinosaurs in the genus *Stegosaurus* have large triangular plates along their spine.

Questions: Are these plates adaptations? What purpose might they serve? How might we test our hypotheses?



A thyreophoran cousin, several times removed:



Worker Bees

Observation: Worker bees (usually) do not reproduce but take an active role in the care of their mother's offspring.

Questions: Why? How can natural selection explain such reproductive altruism?

Autumn Leaves

Observation: Leaves change color in the autumn, sometimes dazzlingly so.

Questions: Why?

Orgasm in Humans

Observation: Humans experience an intense psycho-physiological resposne at the peak of sexual stimulation.

Questions: Why? Is this an evolutionary adaptation? Are there differences between males and females in the applicability of this argument? What would the implication of such differences be?

Bipedality in humans

Observation: Humans walk on two legs in general; closely related primates use arms and legs during typical locomotion.

Questions: Why?