Why is the Problem of Macroevolution Still Unsolved?

University of Minnesota-Morris

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Paul A. Nelson
Fellow
Discovery Institute
www.discovery.org/csc
Biola University
www.biola.edu

Outline of talk

1. What is the "problem" of macroevolution?

2. What aspects of this problem challenge the current theory of evolution?

3. What explanatory options might the possibility of intelligent design provide?

A working definition of "evolution"

Organisms are related by descent with modification from a common ancestor, and came to be via natural causes only.

A working definition of "intelligent design"

The action (agency) of intelligent causes may appropriately be invoked in scientific explanation – and there is evidence that such a cause has acted in life's history.

1. What is the problem of macroevolution?

Facing unsolved problems – answering open questions – is not a shortcoming of science.

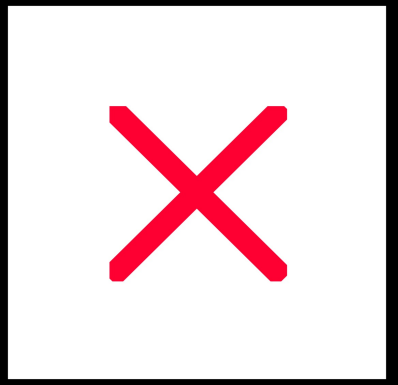
That's what science is all about.

Here are some biological open questions:

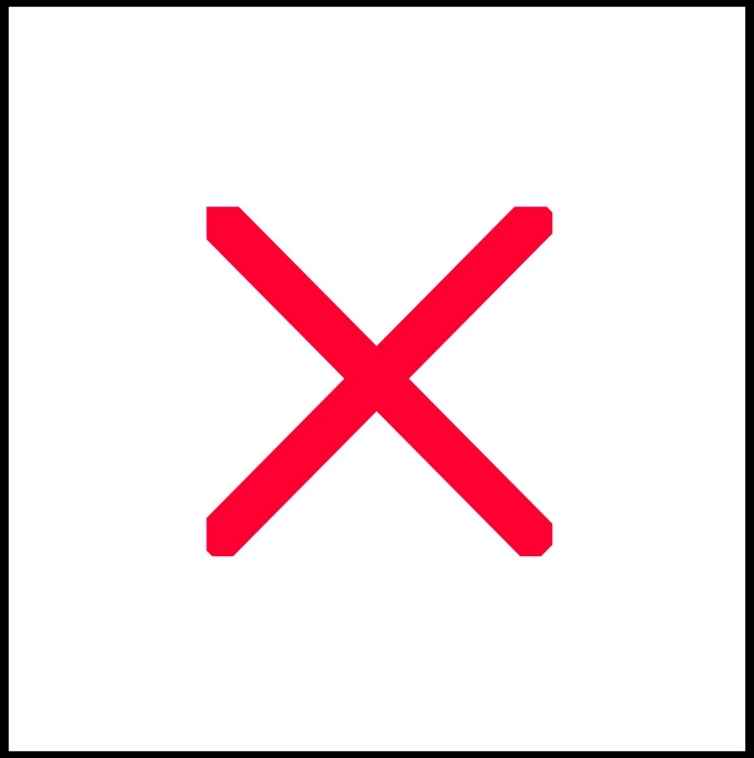
1. How does the brain store memories?
2. How is development regulated?
3. What are the mechanisms of speciation?
4. How does virulence in bacteria arise?

But not every question we put to nature can be answered as we might like – that is, in the terms that we prefer.

Let's suppose it is 2035, and humans have colonized Mars.



I want to talk to my nephew who works in a Martian laboratory.



So I put this question to nature – that is, *I have this unsolved science problem:*

"How can Earth dwellers communicate in real time with Mars dwellers?"

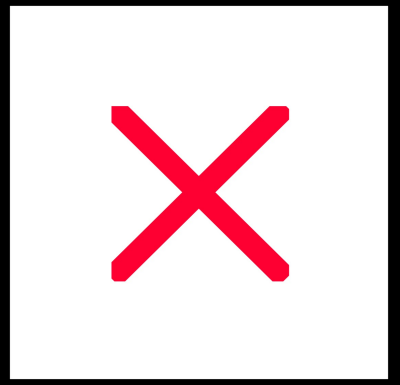
Thus, our research problem: How can we communicate in real time with inhabitants of Mars?

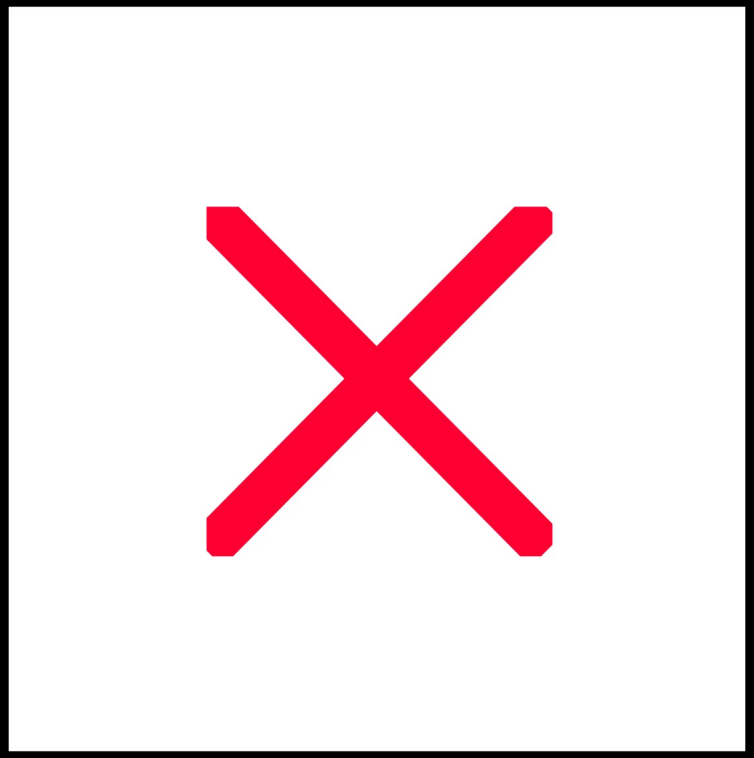
And the answer is…?

The question is ill-posed.
We can *ask* it, but – given current physics, anyway – we won't get an answer.

At its closest (in autumn), Mars is approximately 35,000,000 miles away.

The speed of light (signal transmission) is ~ 186,000 miles per second.





$$\frac{35{,}000{,}000}{186{,}000} = 188.172 \text{ sec}$$

(3.13 minutes)

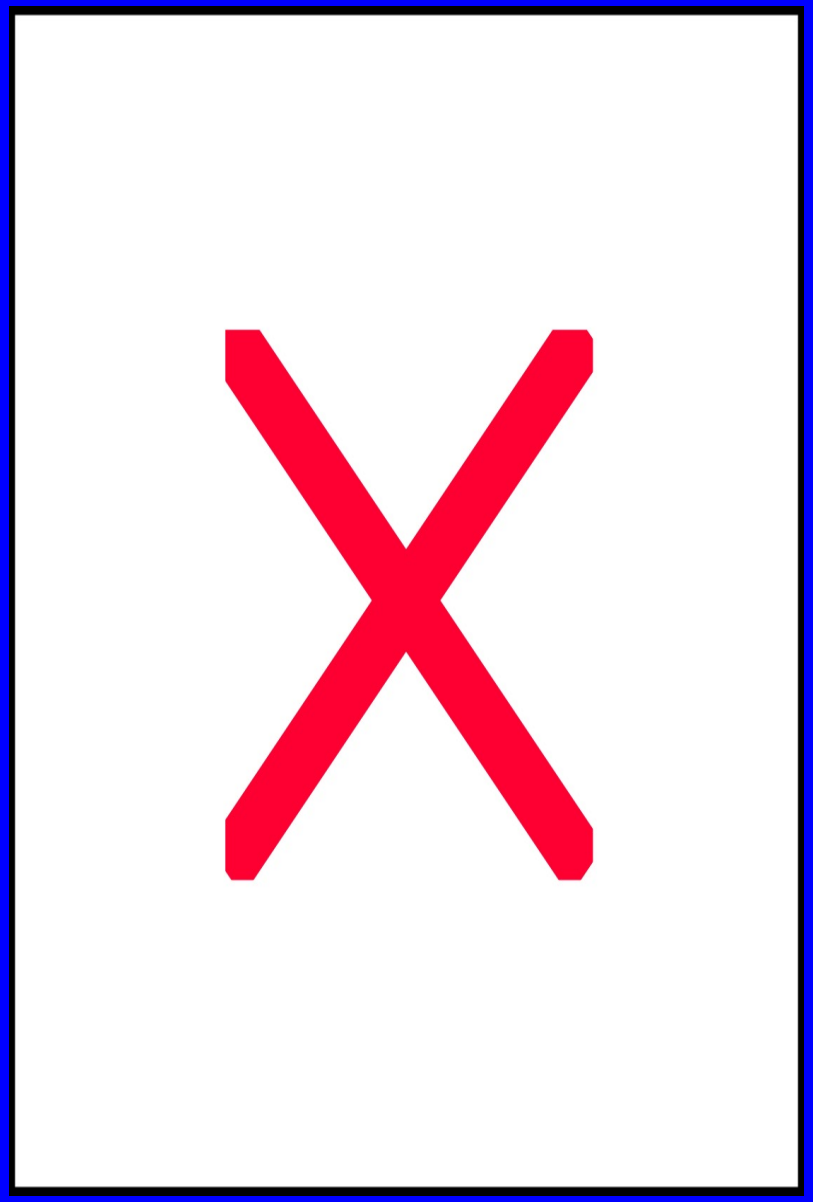
The problem we want to be solved *cannot be* solved. Nature doesn't work that way.

Not every question we put to nature can be answered as we might like.

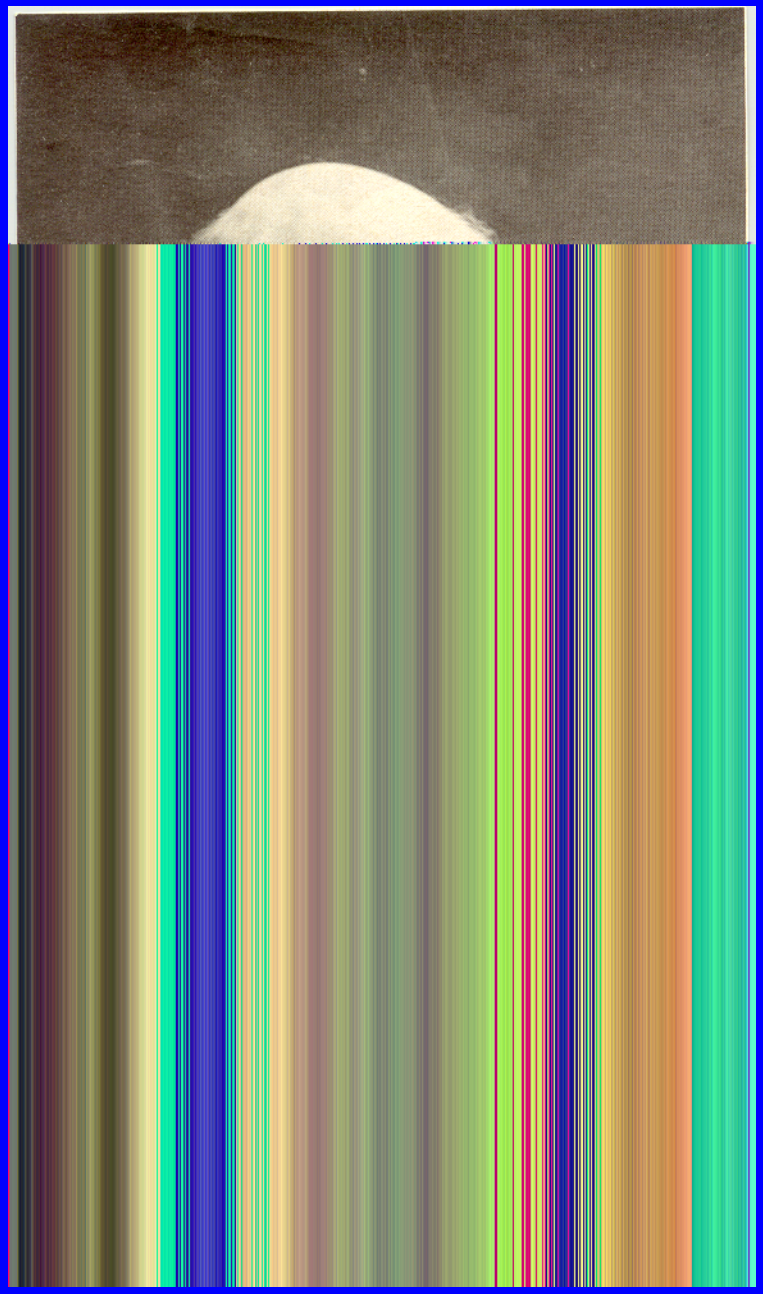
Some problems persist as "unsolved" because they are predicated on incorrect assumptions.

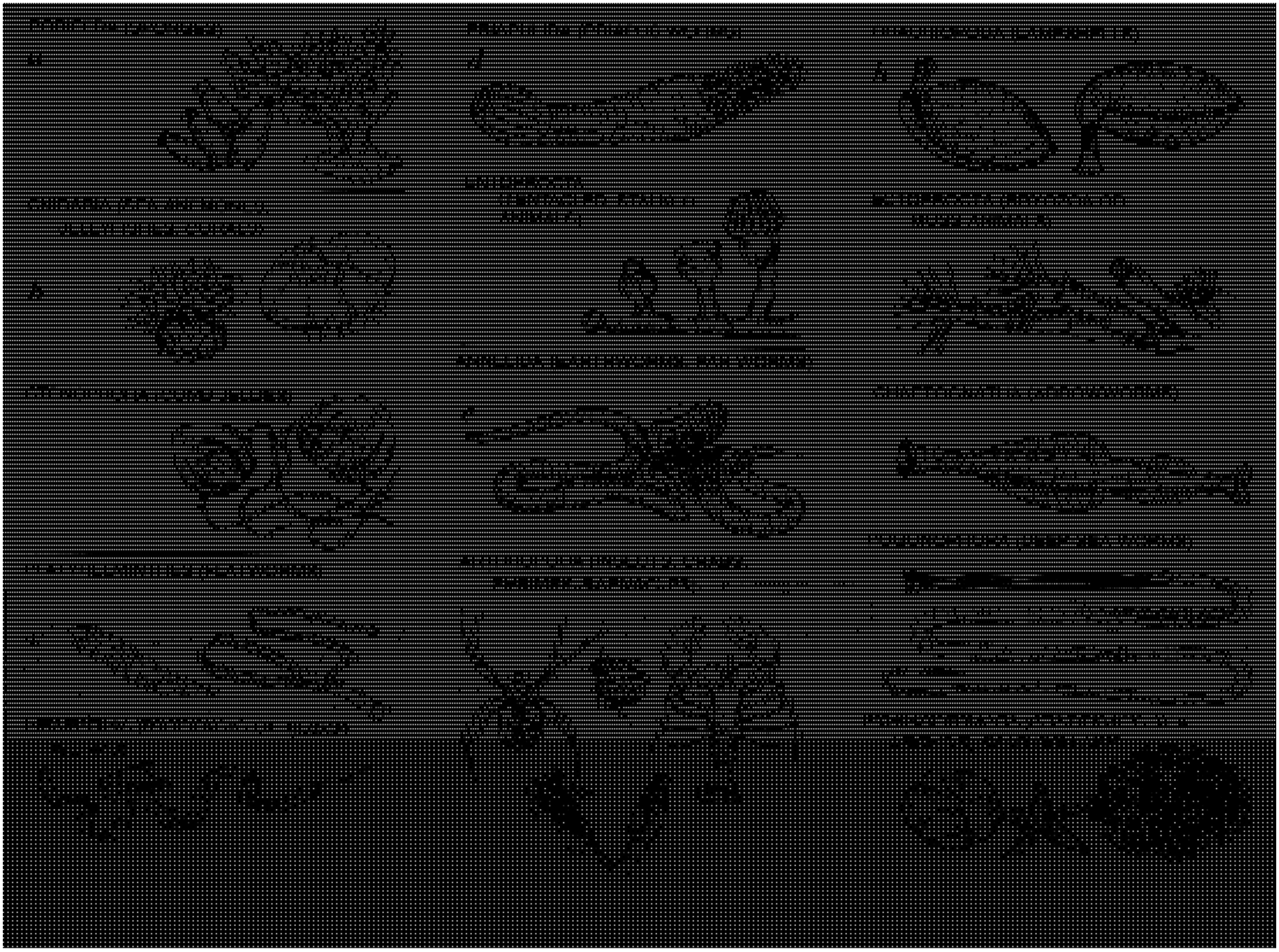
Science doesn't solve such problems; rather, we find the wrong assumptions, and dissolve the problem as ill-posed.

Is the problem of macroevolution still unsolved because we haven't looked long enough for an answer – or because the question we are putting to nature is ill-posed?



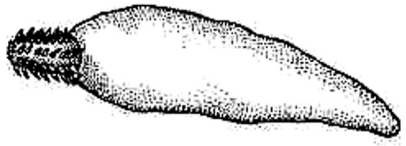
Time magazine (1995) covers Cambrian explosion



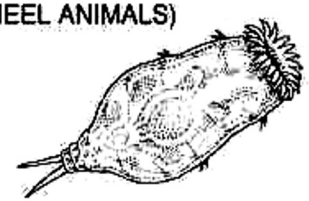


ACANTHOCEPHALA
(SPINY-HEADED WORMS)

d

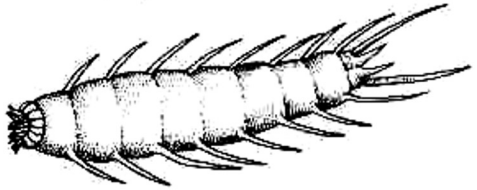


ROTIFERA (WHEEL ANIMALS)

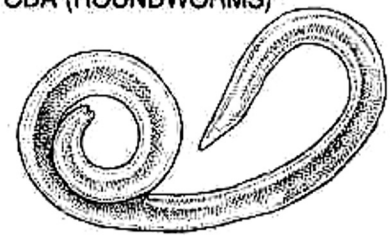


GASTROTRICHA (SCALED WORMS)

KINORHYNCHA (SPINY-SKINNED WORMS)



NEMATODA (ROUNDWORMS)



SIPUNCULIDA (PEANUT WORMS)

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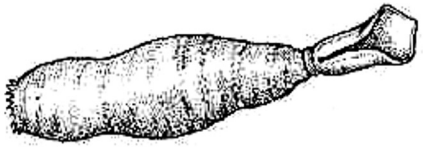
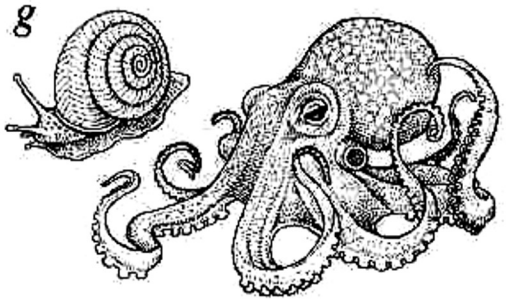
ECHIUROIDEA (SAUSAGE-SHAPED
MARINE WORMS)



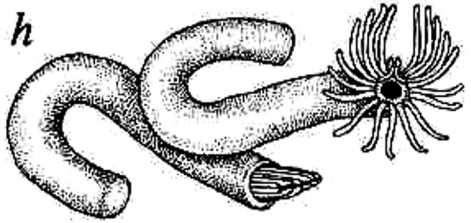
MOLLUSCA (CLAMS, SNAILS,
OCTOPUS, SQUID)

g

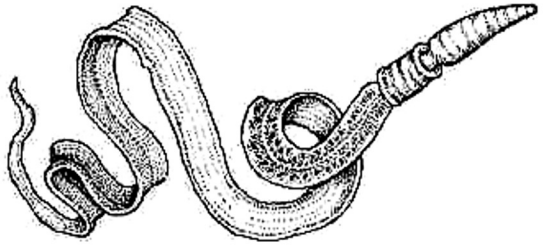


PHORONIDA (HORSESHOE WORMS)

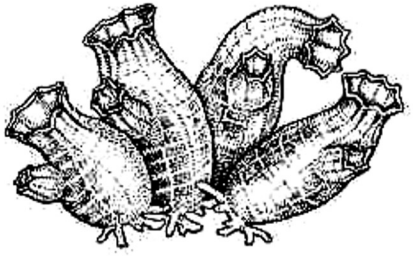
h



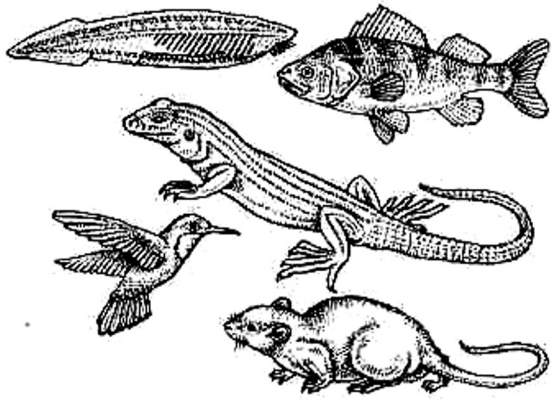
HEMICHORDATA (ACORN WORMS)



UROCHORDATA (SEA SQUIRTS)

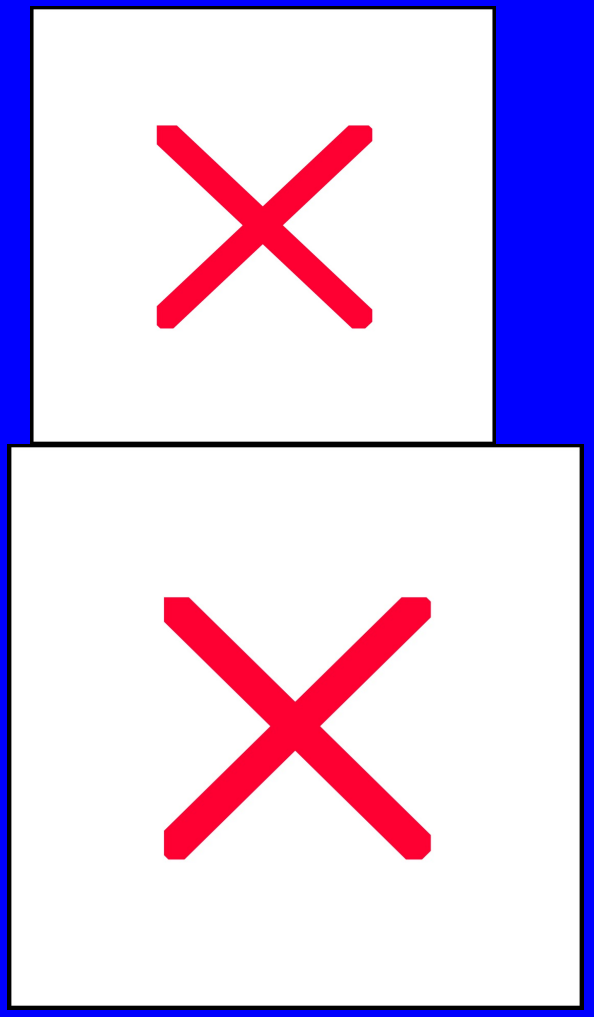


CHORDATA (AMPHIOXUS, FISHES,
AMPHIBIANS, REPTILES, BIRDS,
MAMMALS)

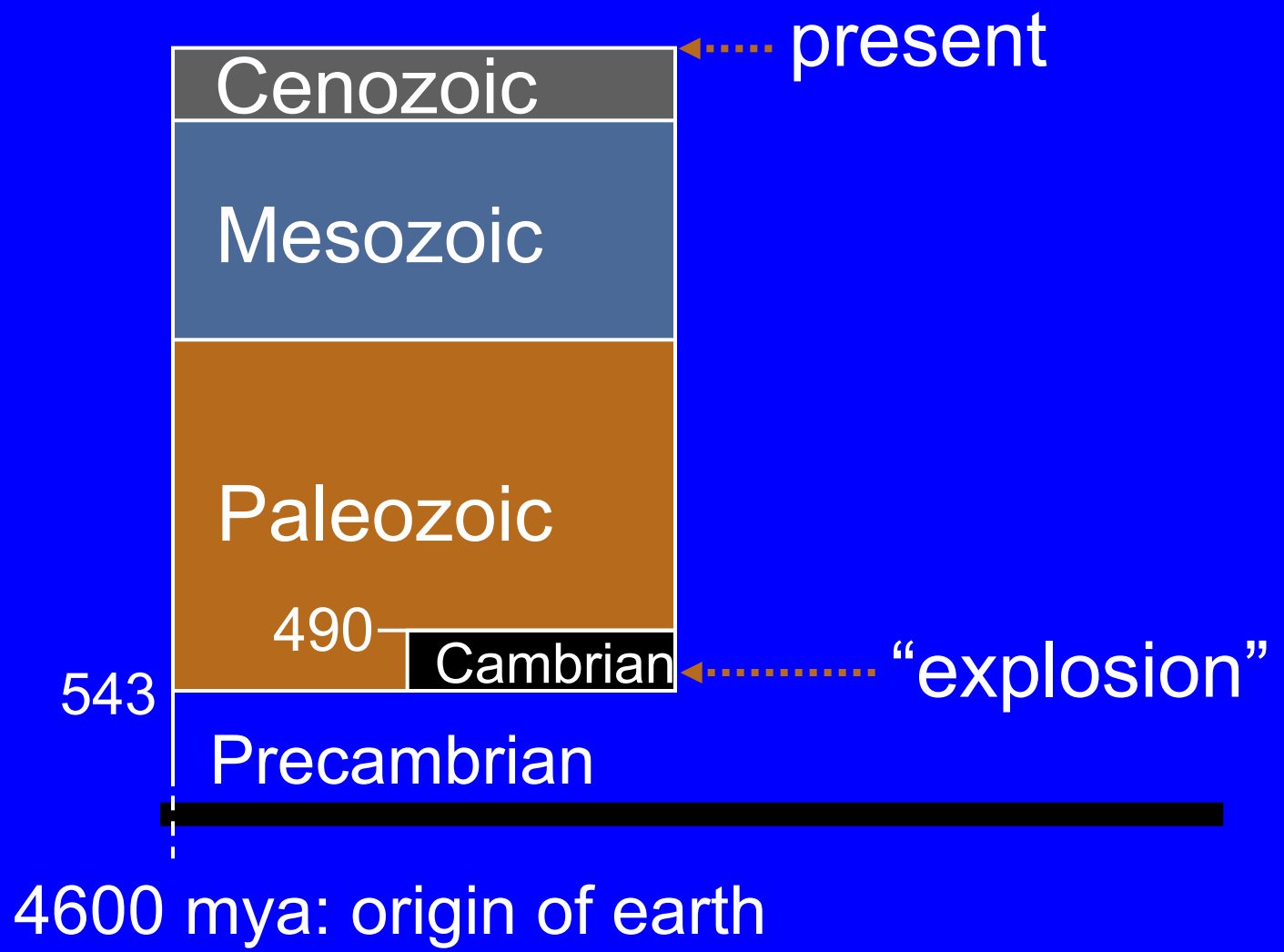


Biological Classification

	Bumble Bee	Polar Bear
Kingdom	Animal	Animal
Phylum	Arthropod	Chordate
Class	Insect	Mammal
Order	Hymenoptera	Carnivora
Family	Apidae	Ursidae
Genus	*Bombus*	*Ursus*
Species	*terricola*	*maritimus*

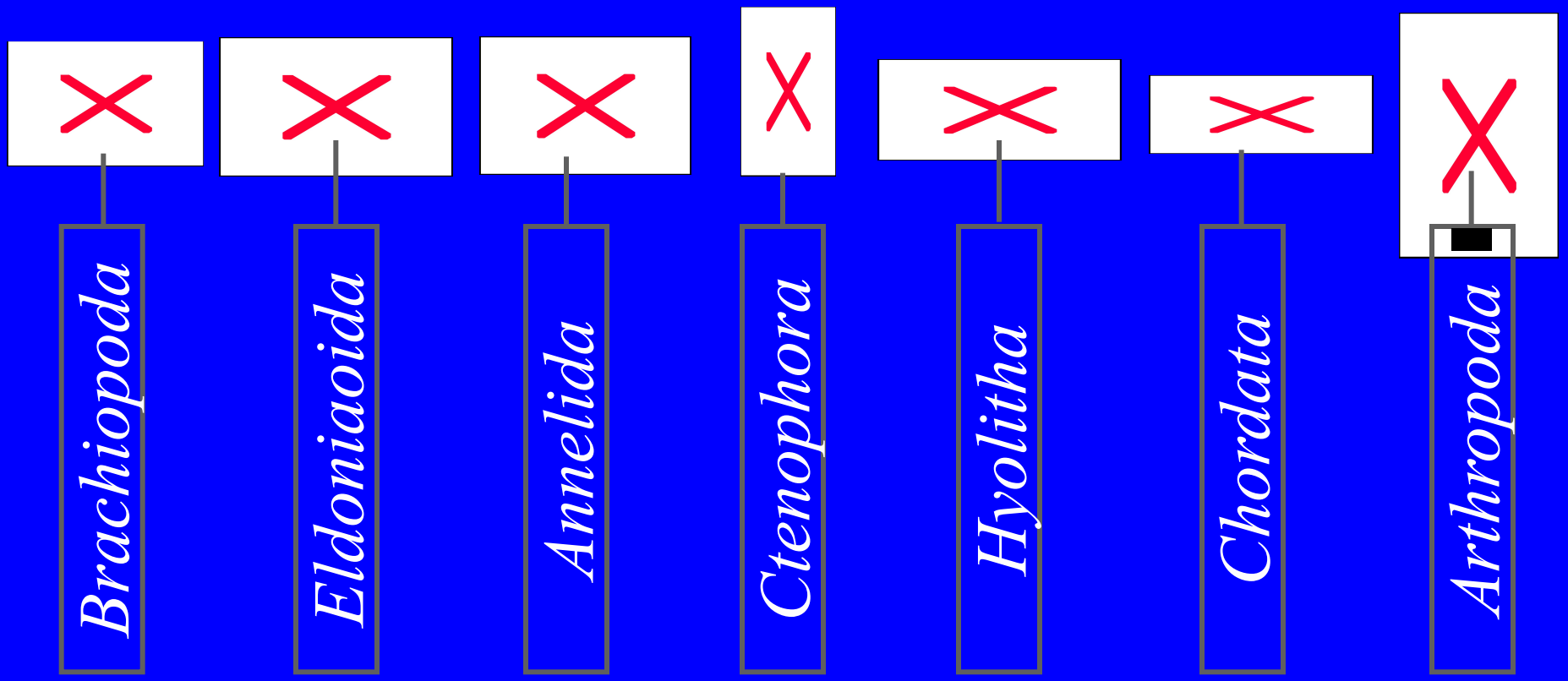


Earth History: Geologic Time Scale



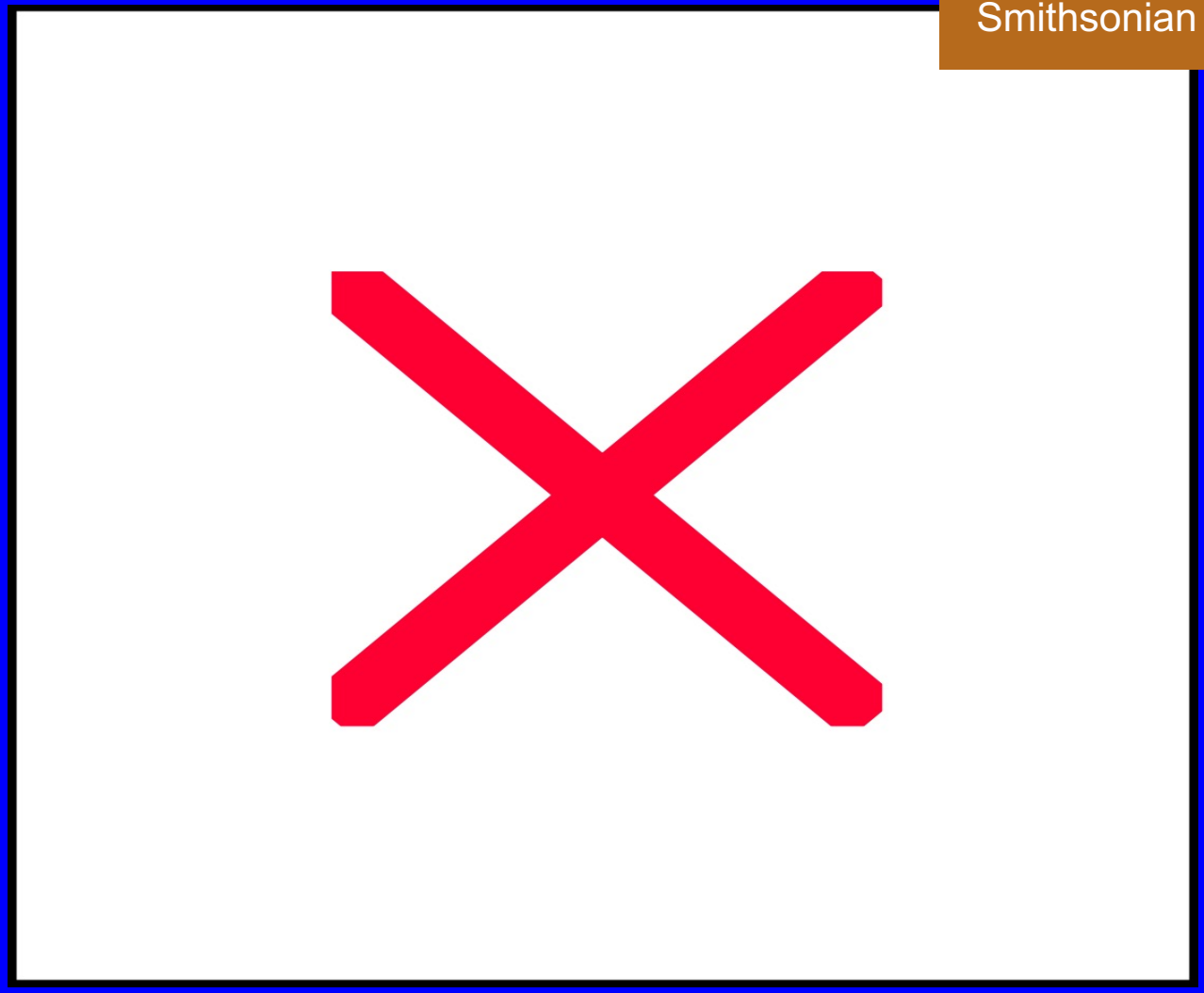
A dramatic biological event

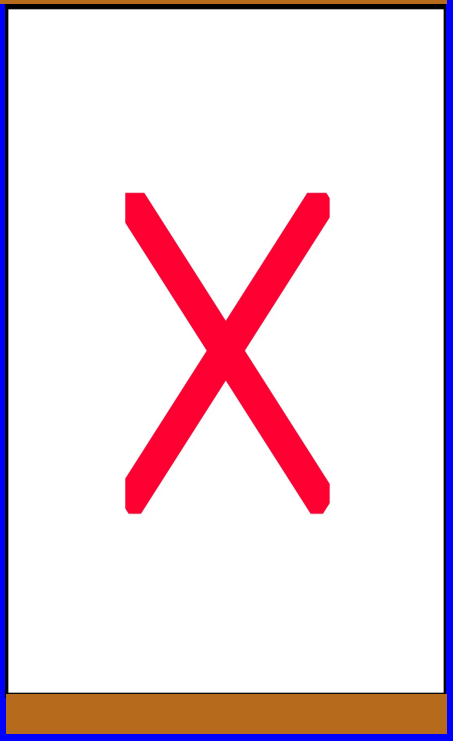
First appearance of most animal body plans



Location: Burgess Shale (Canada)

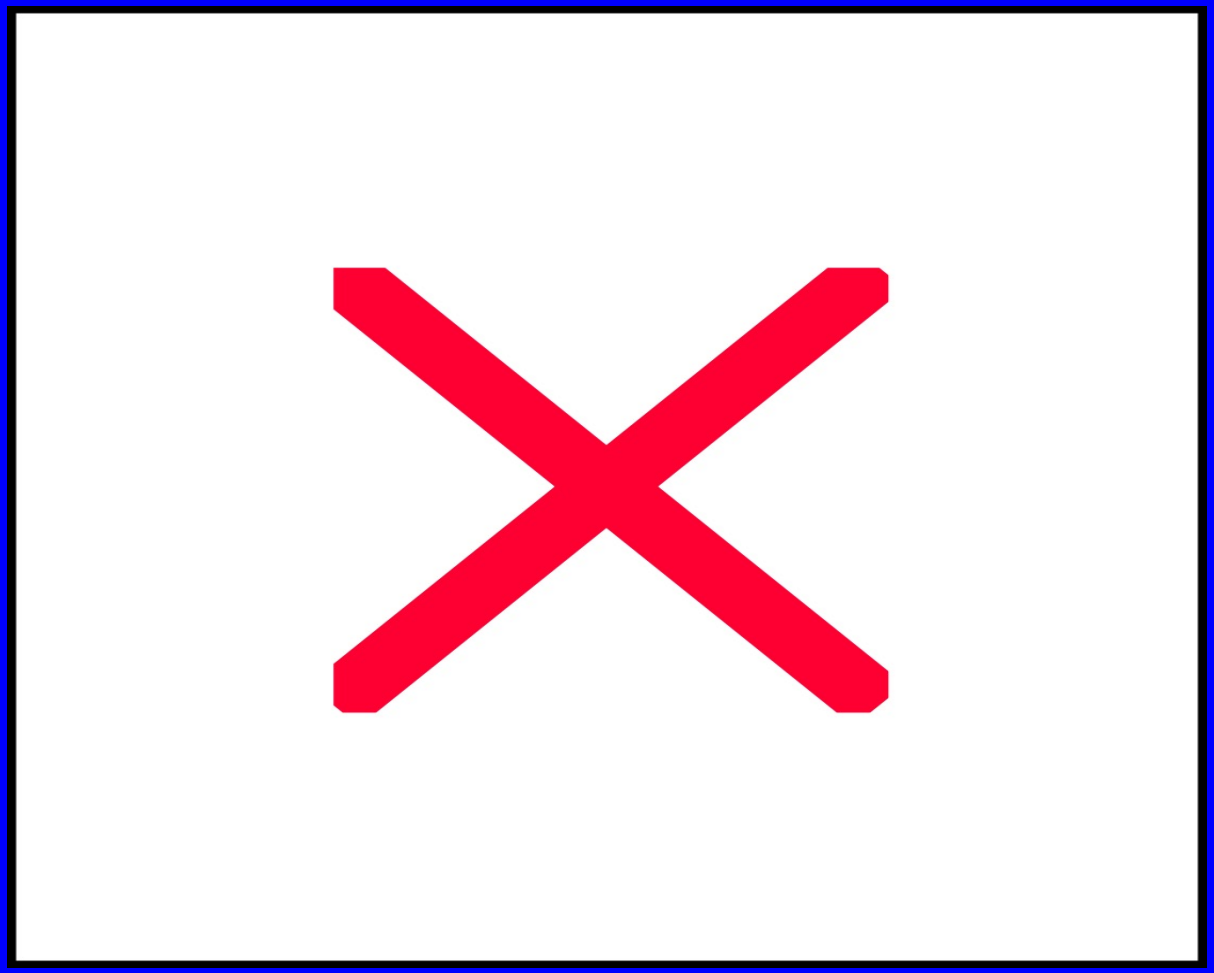
Smithsonian Institution Press (1994)

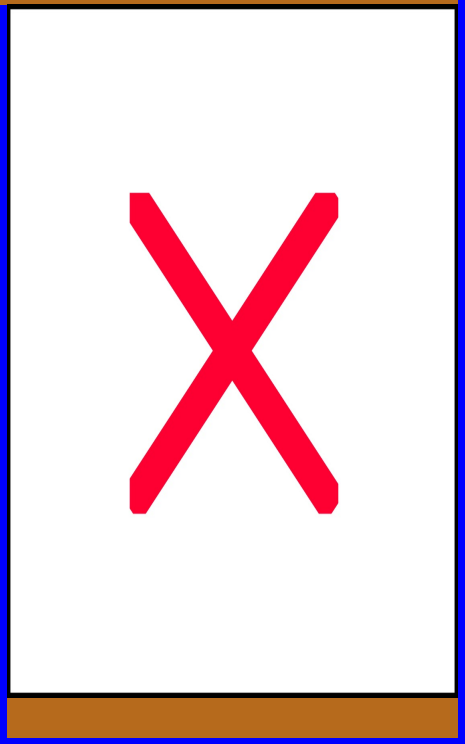




Location: Chengjiang, China

National Museum of Natural Science (Taiwan, 1996)

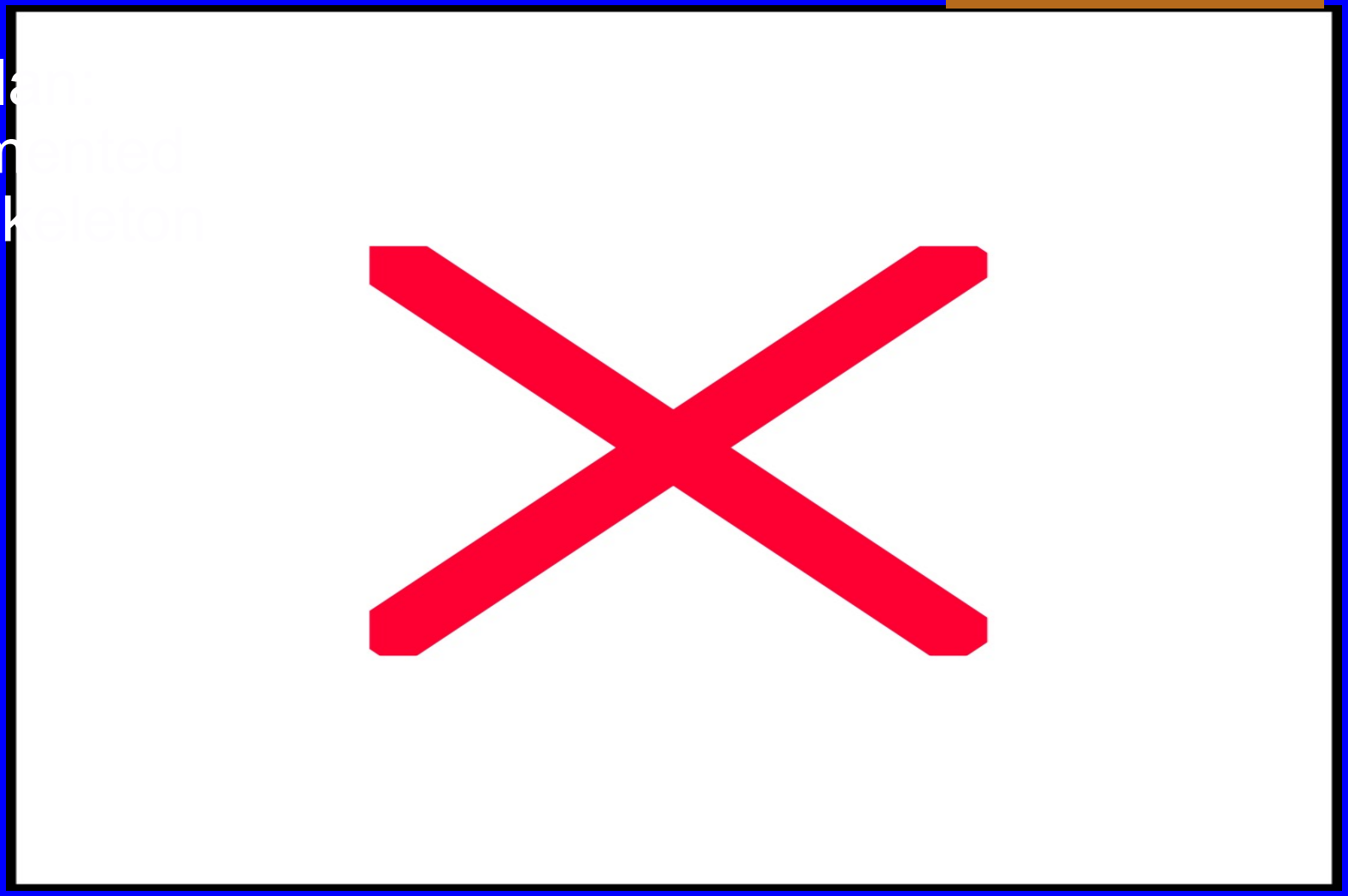




Phylum: *Arthropoda* Subphylum: *Crustacea*

Genus: *Waptia*

Body Plan:
1. Segmented
2. Exoskeleton



Phylum: *Chordata* Subphylum: *Vertebrata*

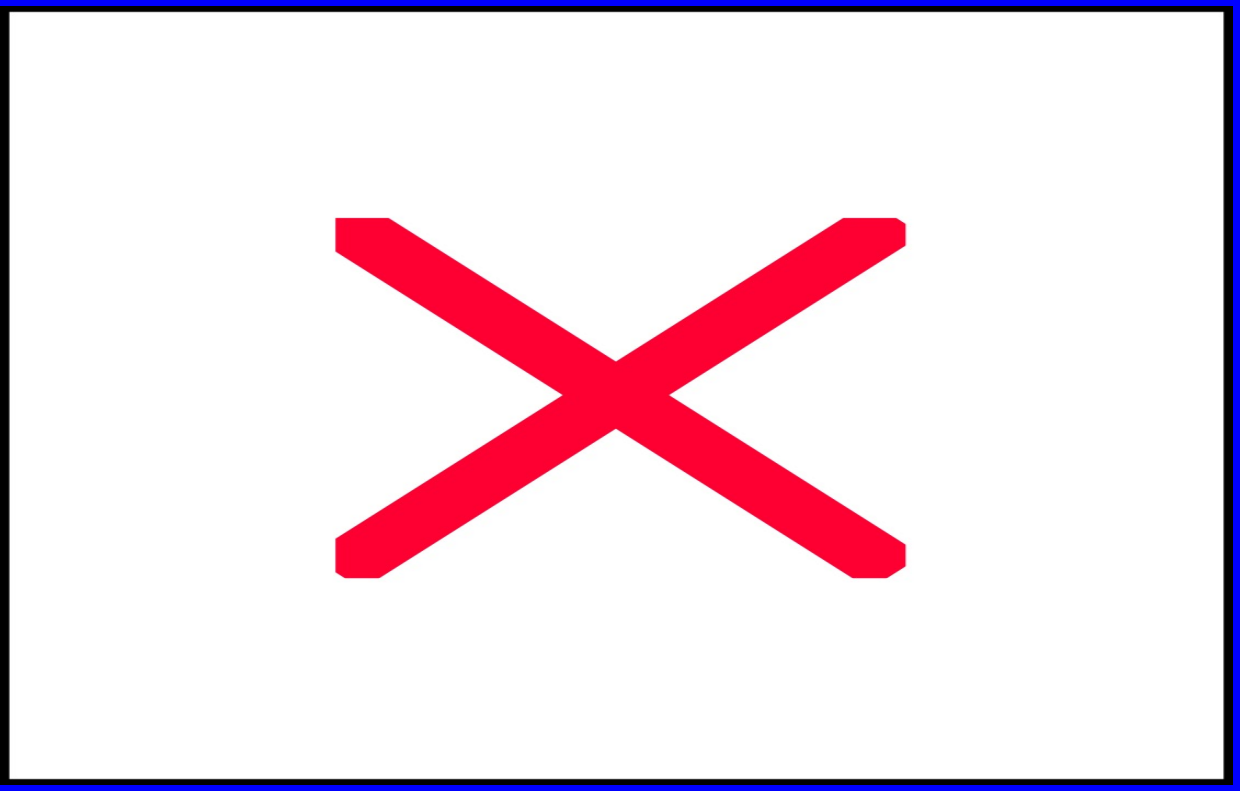
Genus & species: *Myllokunmingia fengjiaoa*

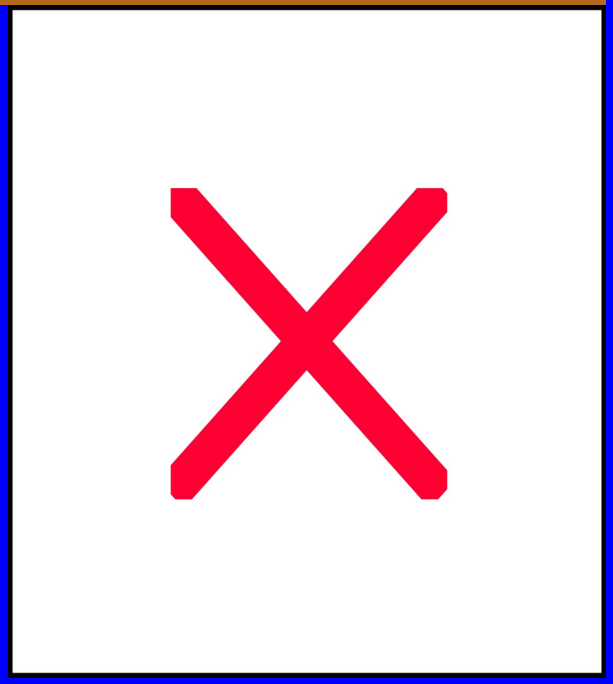
Body Plan:

Phylum: *Brachiopoda*

Genus & species: *Heliomedusa orienta*

Body Plan:
1. Shell of two unequal parts
2. Feeding organ: lophophore





The fossil ancestry of these and other phyla is described by Berkeley paleontologist James Valentine as "cryptogenetic":

"*cryptogenetic*: A clade or taxon, the ancestry of which cannot be traced from fossil evidence."

James W. Valentine,
On the Origin of Phyla
(University of Chicago Press, 2004, p. 35)

But the puzzle of the Cambrian Explosion is not really a *paleontological* (i.e., fossil) problem.

The fossils just make the puzzle more dramatic.

The real problem arises from the way that animals are constructed by the process of development.

2. What aspects of this problem challenge the current theory of evolution?

Two sub-theories stemming from Darwin (1859):

1. The common descent of the Metazoa (the animals)

2. Natural selection as the main cause of biological novelty

If, within a species or population, the individuals

a. vary in some trait q -- the condition of **variation**;

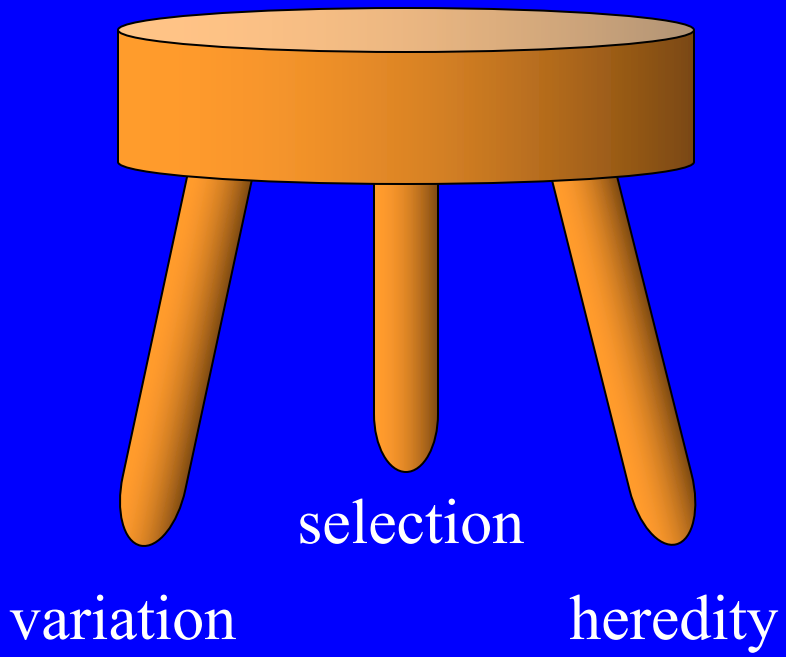
b. leave different numbers of offspring in consistent relation to the presence or absence of trait q -- the condition of **selection**;

c. transmit trait q faithfully between parents and offspring -- the condition of **heredity**;

then the frequency of trait q will differ predictably between the population of all parents and the population of all offspring. (Lewontin 1978; Endler 1986)

The requirements of natural selection:

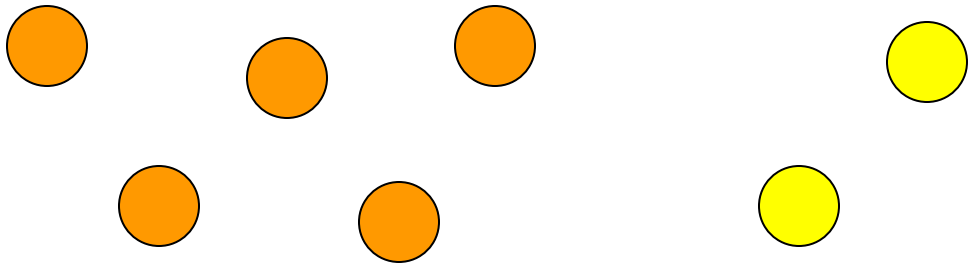
- variation
- selection
- heredity

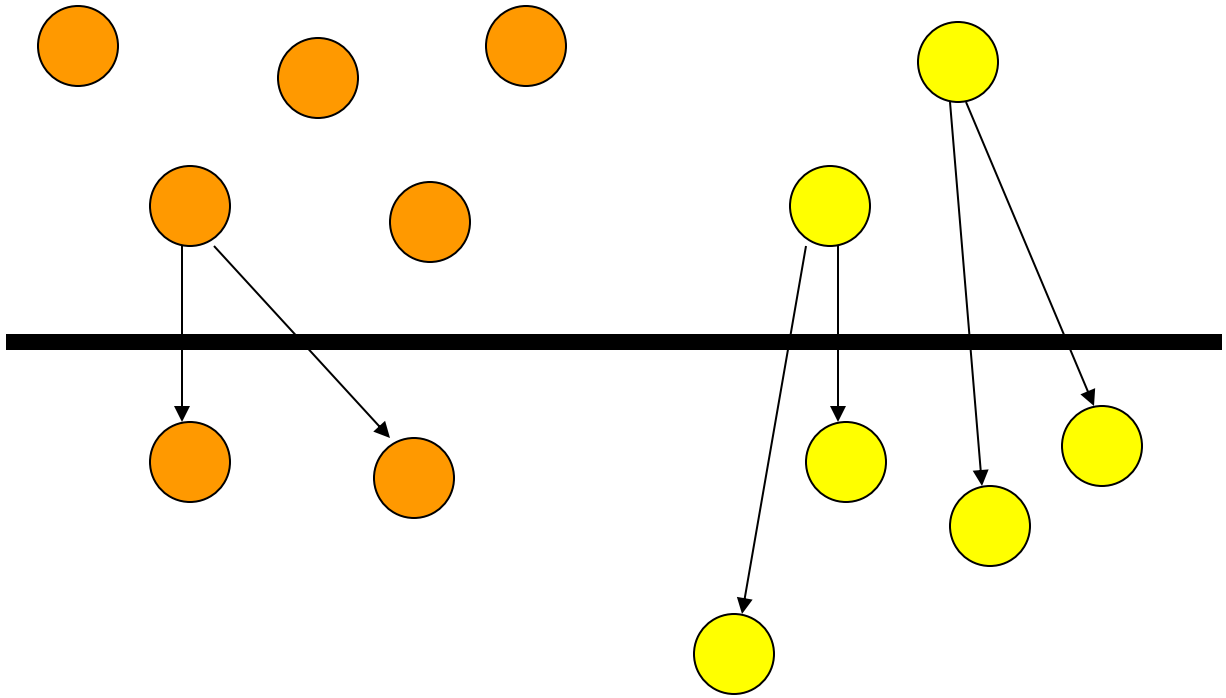


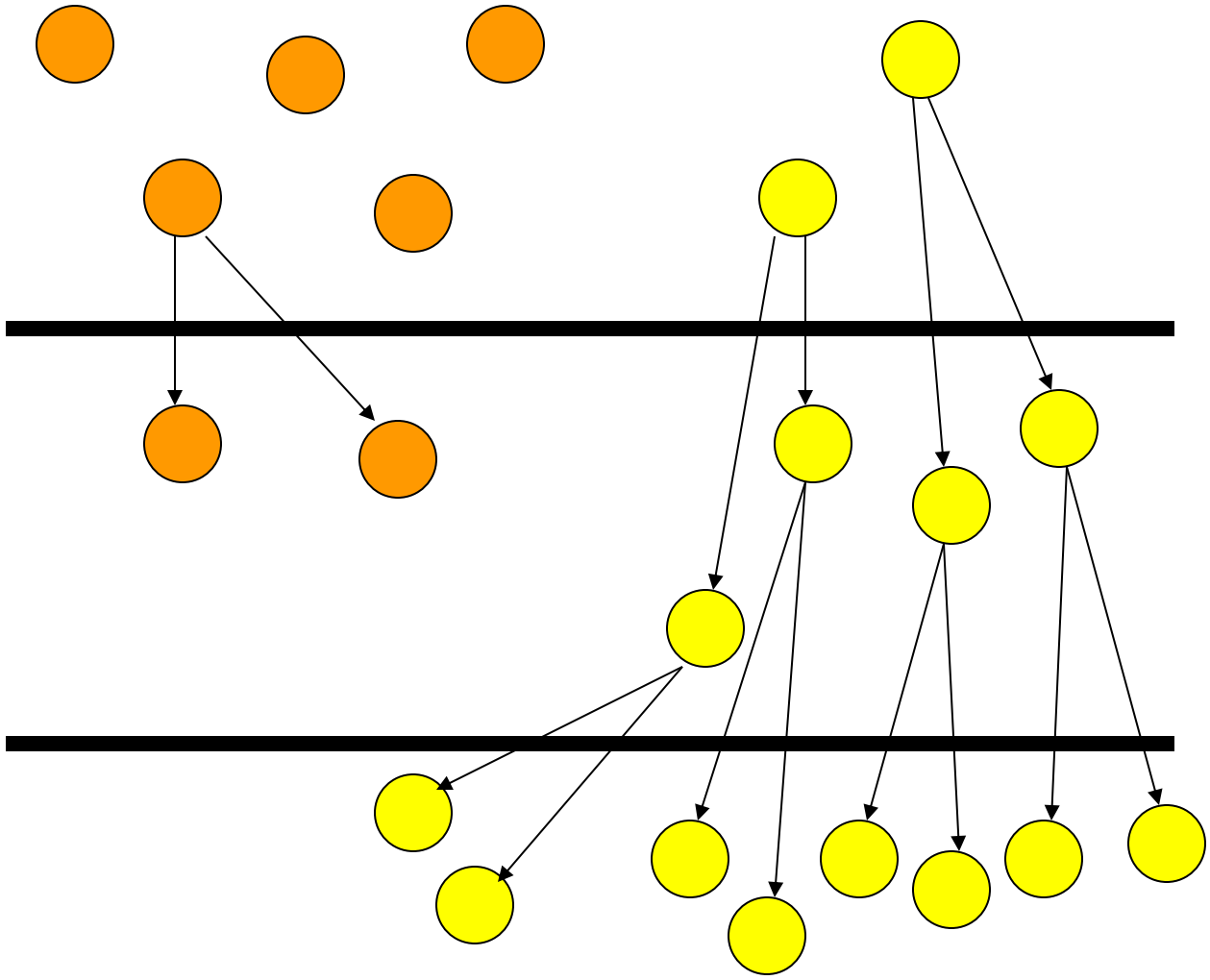
The requirements of natural selection:

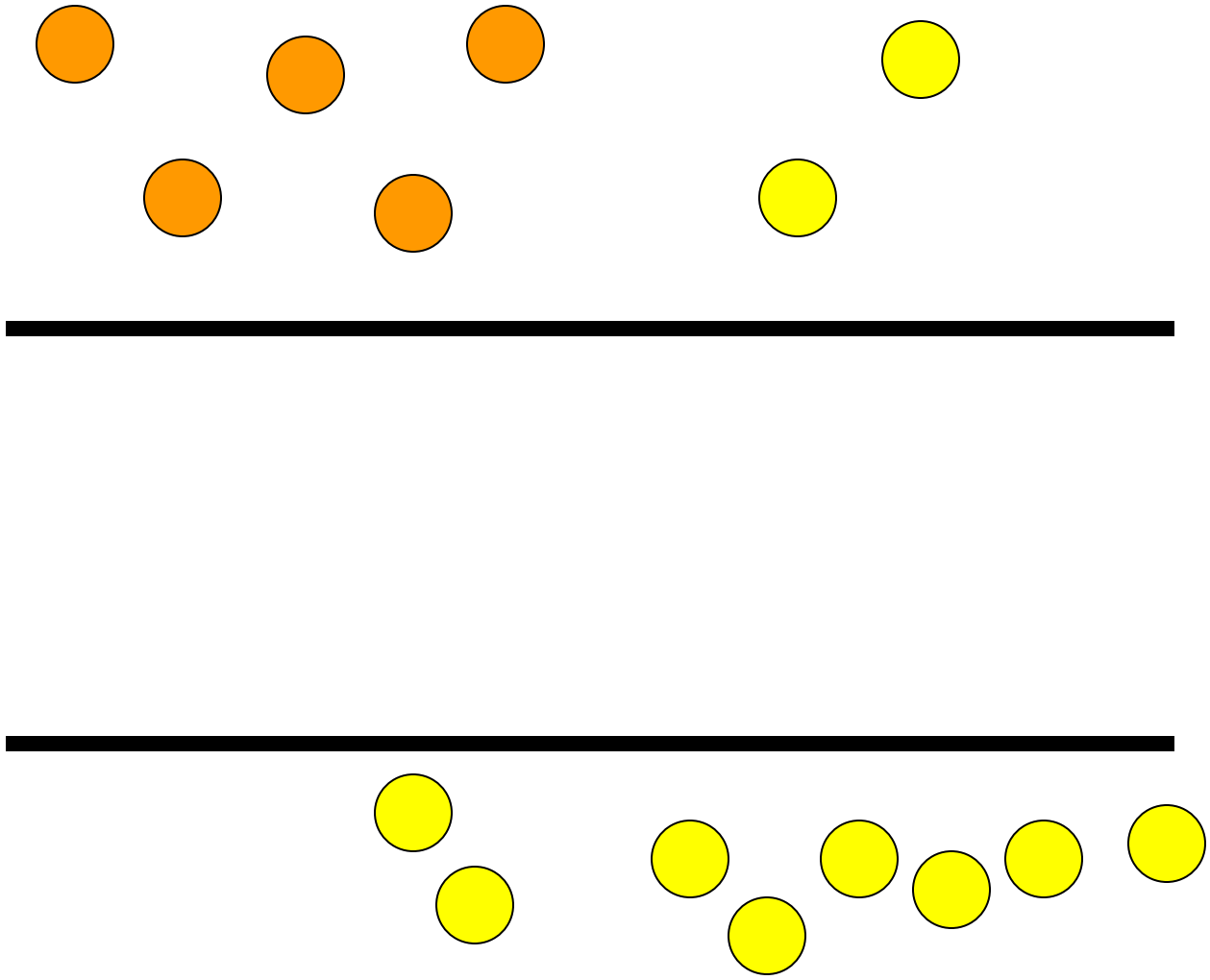
- variation
- selection
- heredity

Bottom line: if you cannot leave viable offspring, then as far as natural selection is concerned, you're an evolutionary dead end.

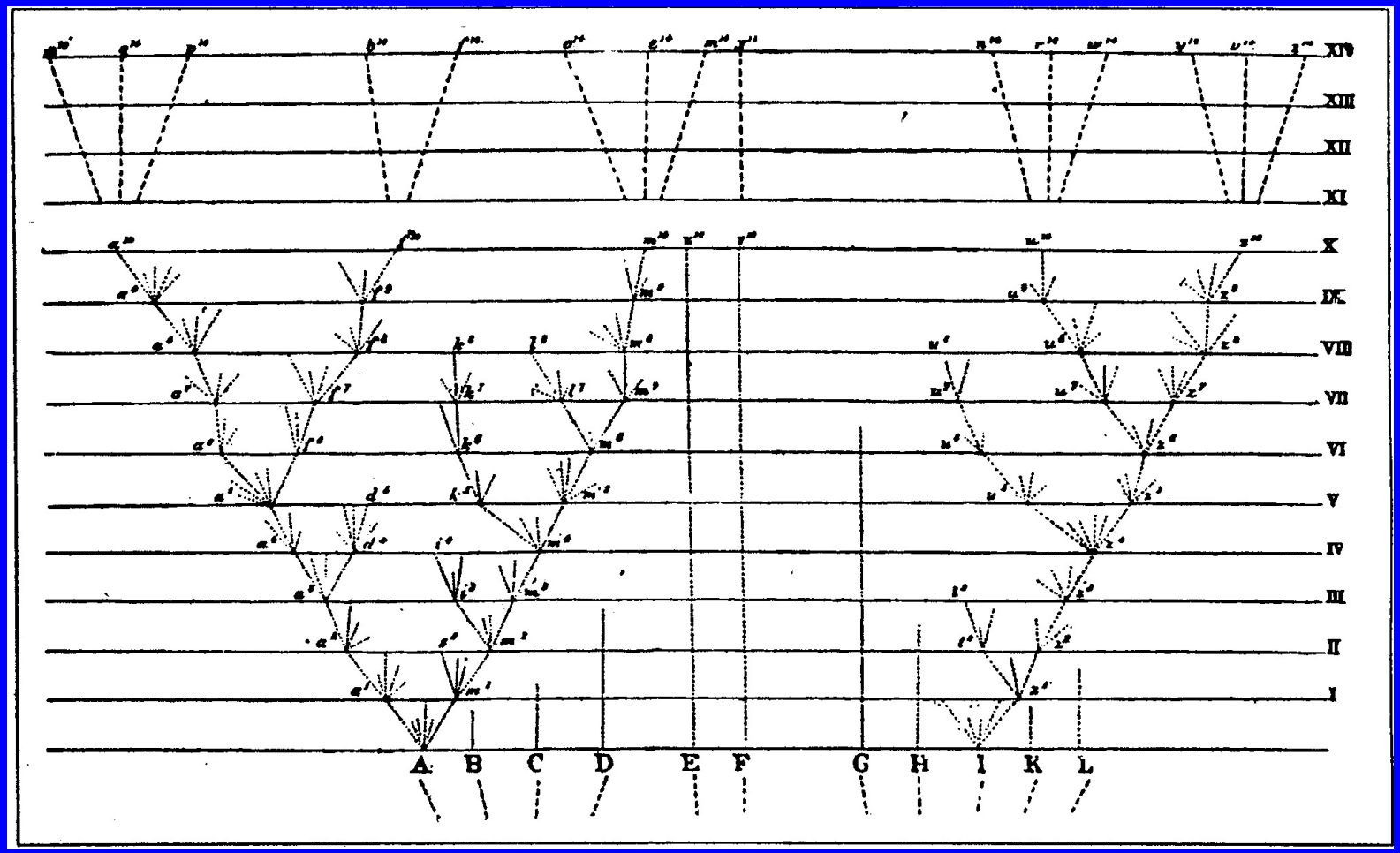




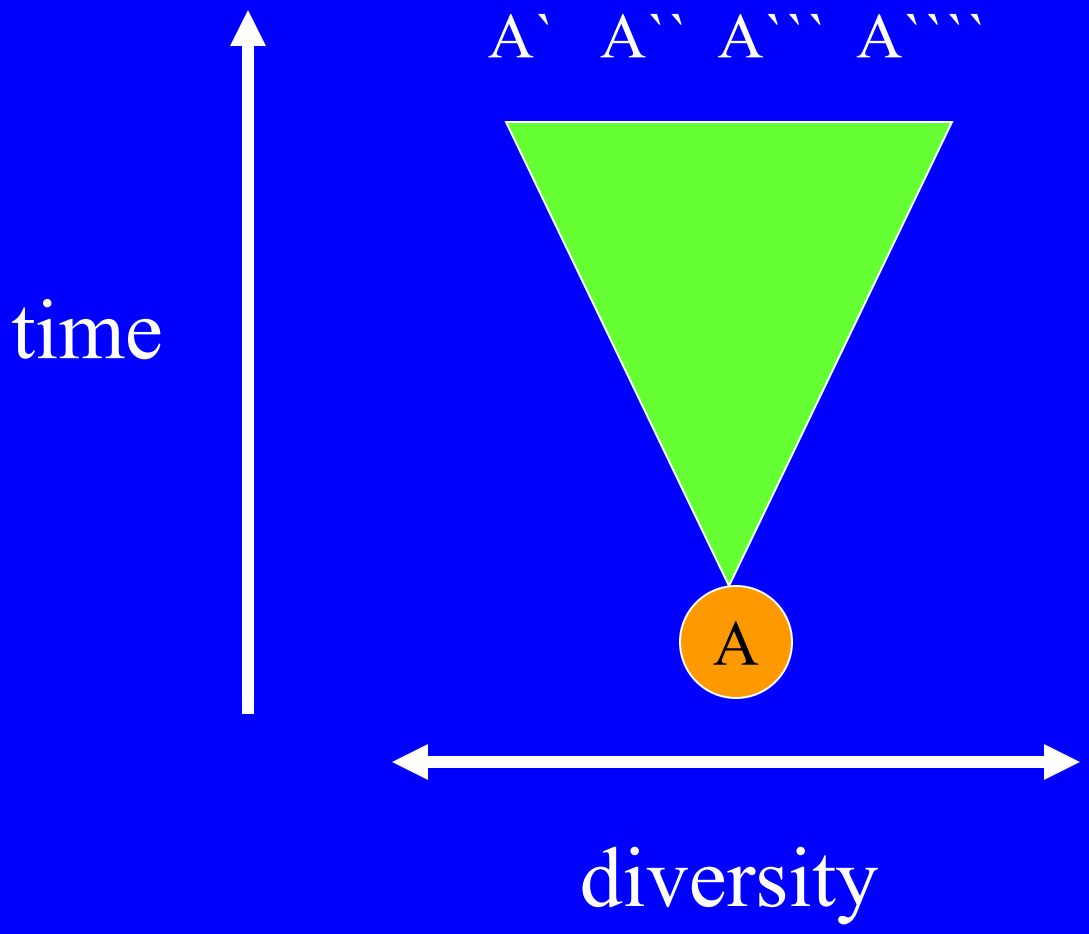




Darwin's (1859, 116) branching diagram



Darwin's recursive (fractal) tree of life



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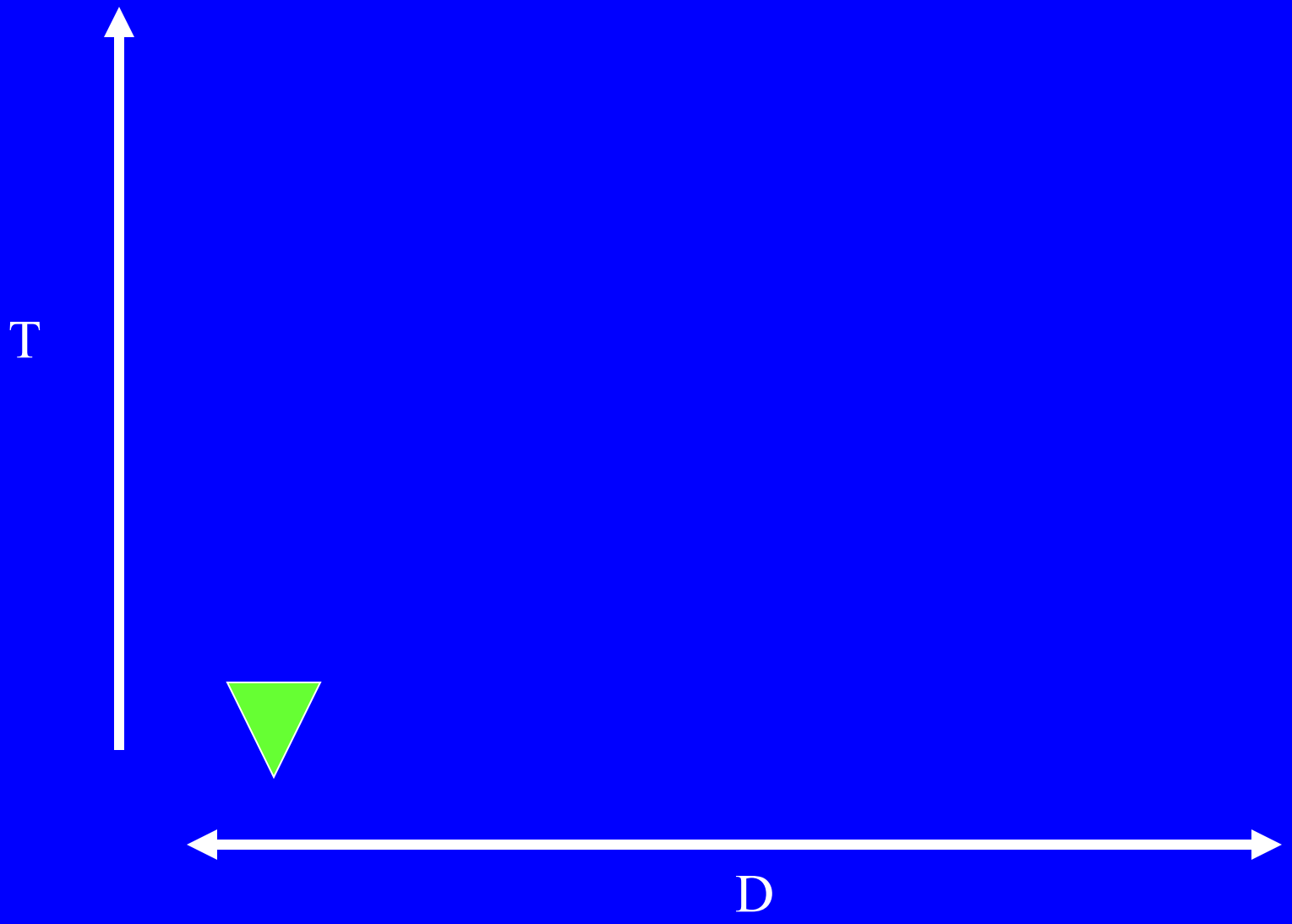

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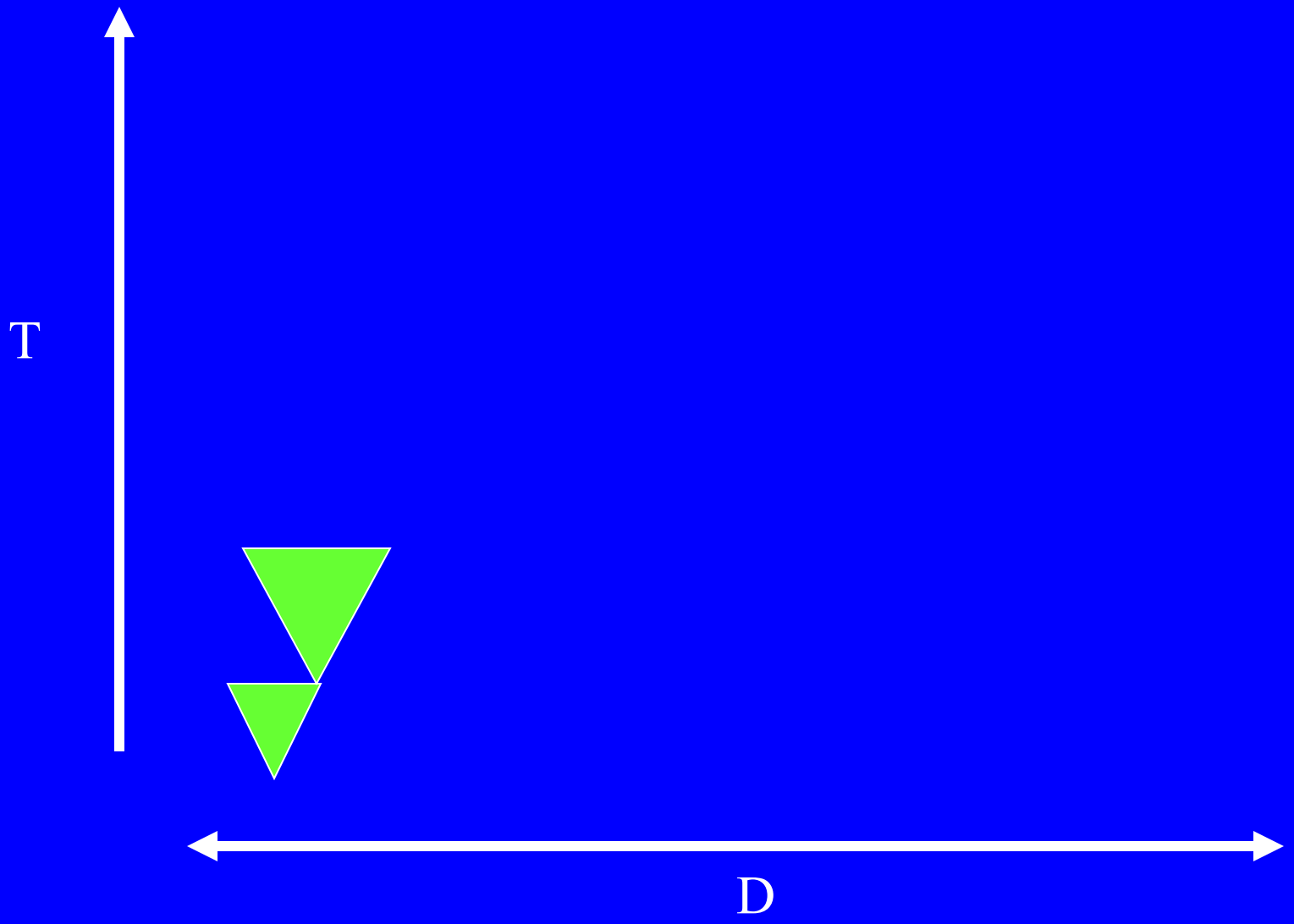

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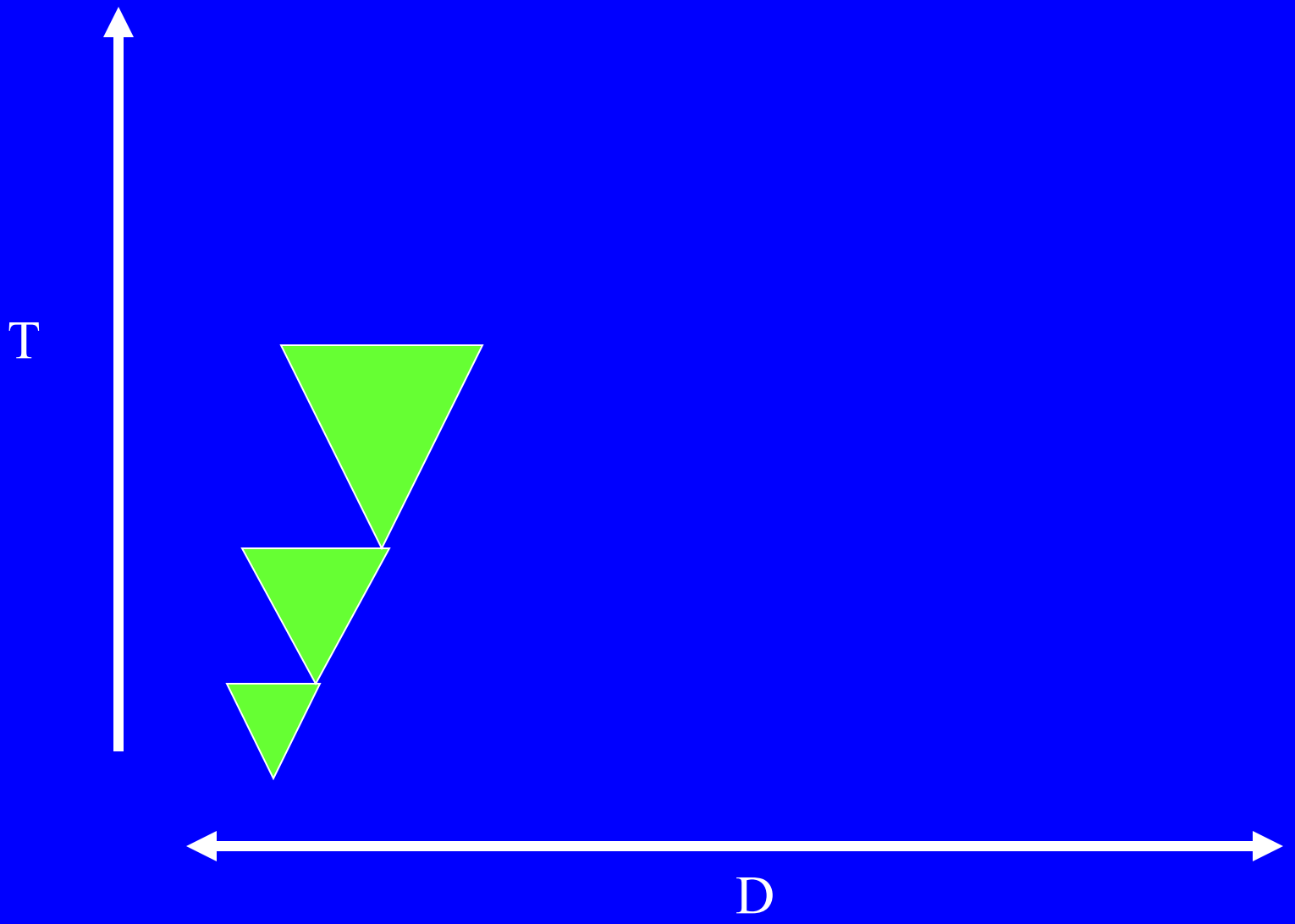

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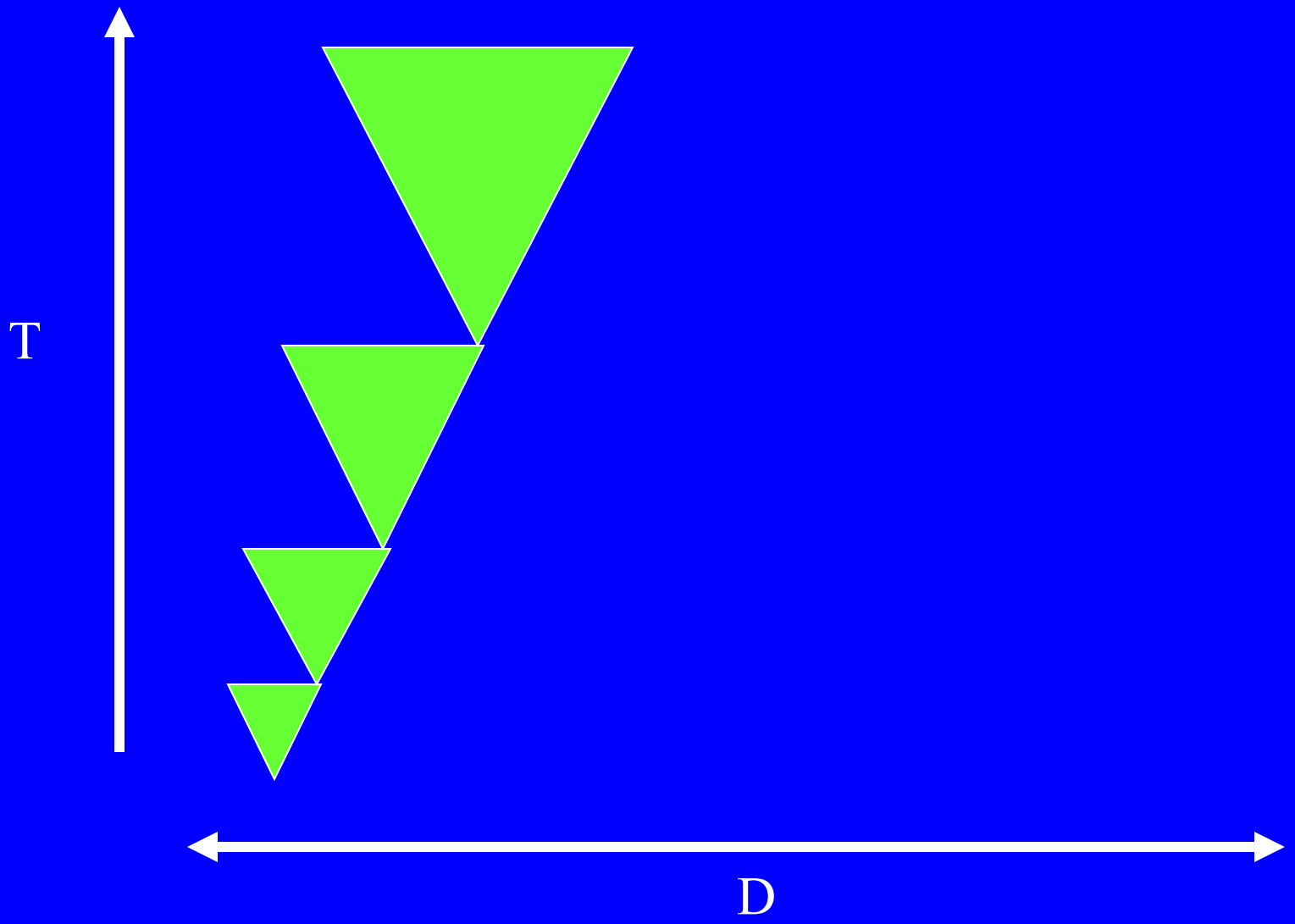

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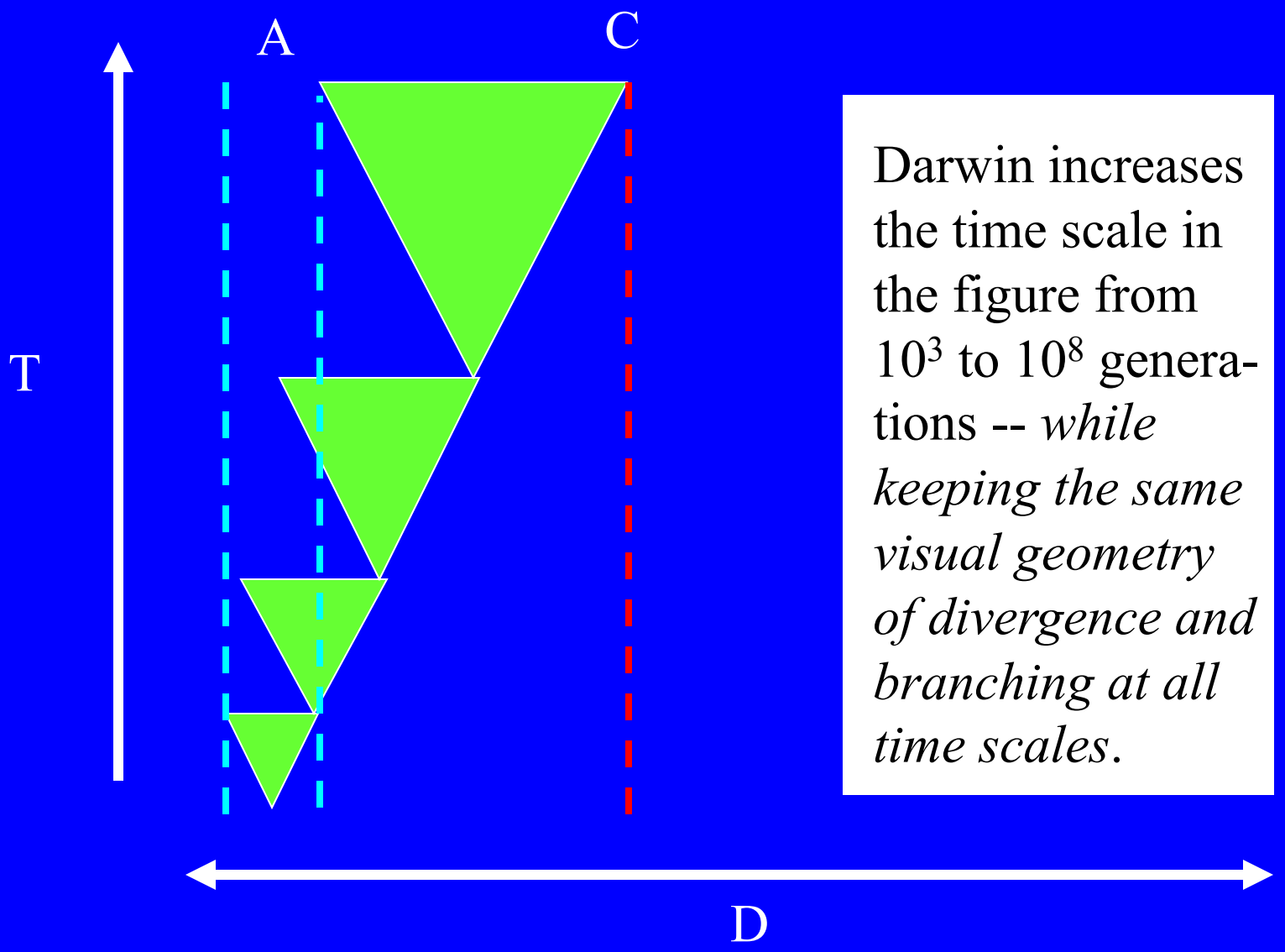


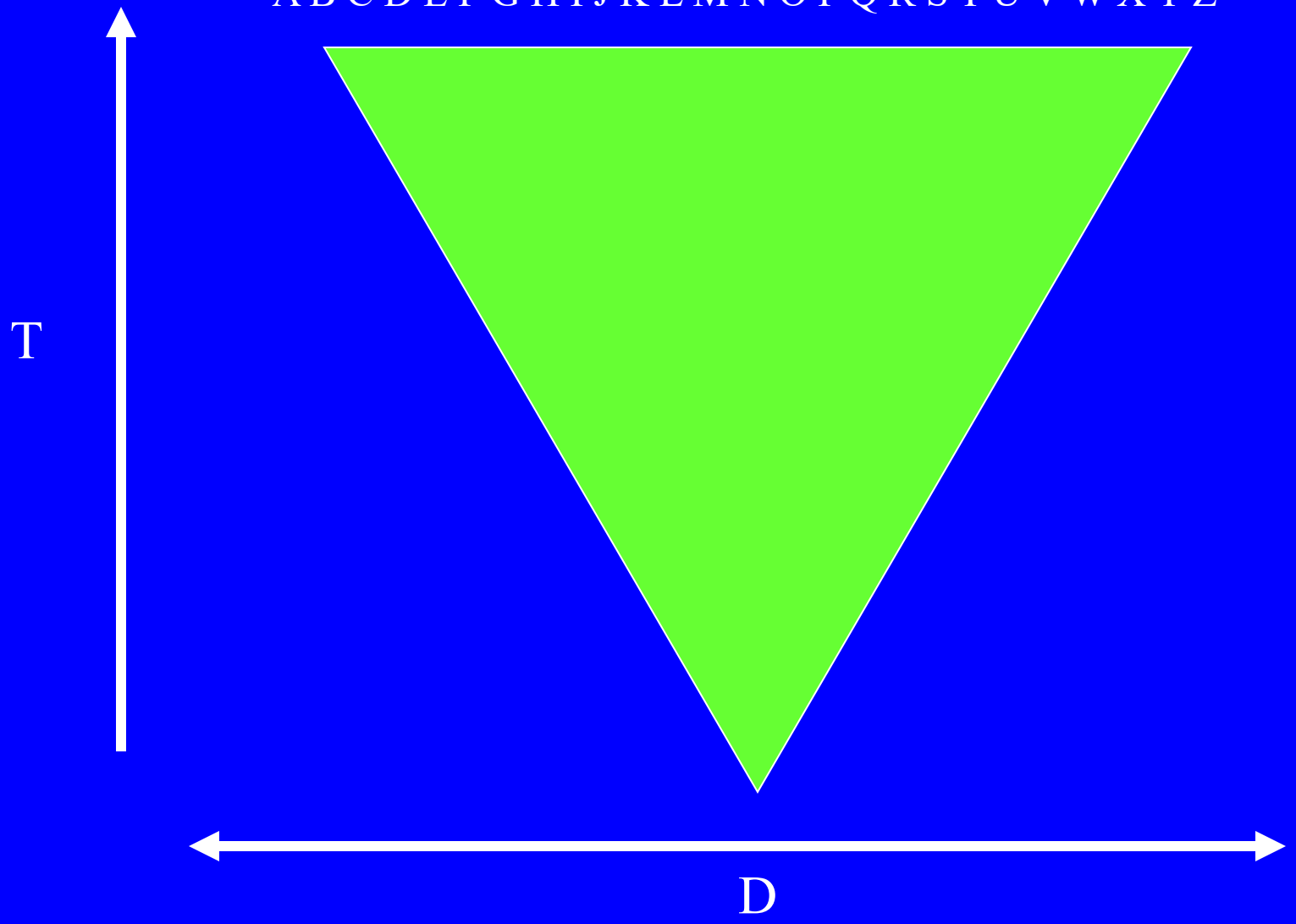
Darwin increases the time scale in the figure from 10^3 to 10^8 generations -- *while keeping the same visual geometry of divergence and branching at all time scales*.

In Darwin's view (although he wouldn't have used these terms), *microevolution* was both necessary and sufficient for *macroevolution*.

But many current evolutionary biologists don't agree. The difficulties begin when we consider some puzzling features at the base of Darwin's figure.

Darwin's recursive (fractal) tree of life

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



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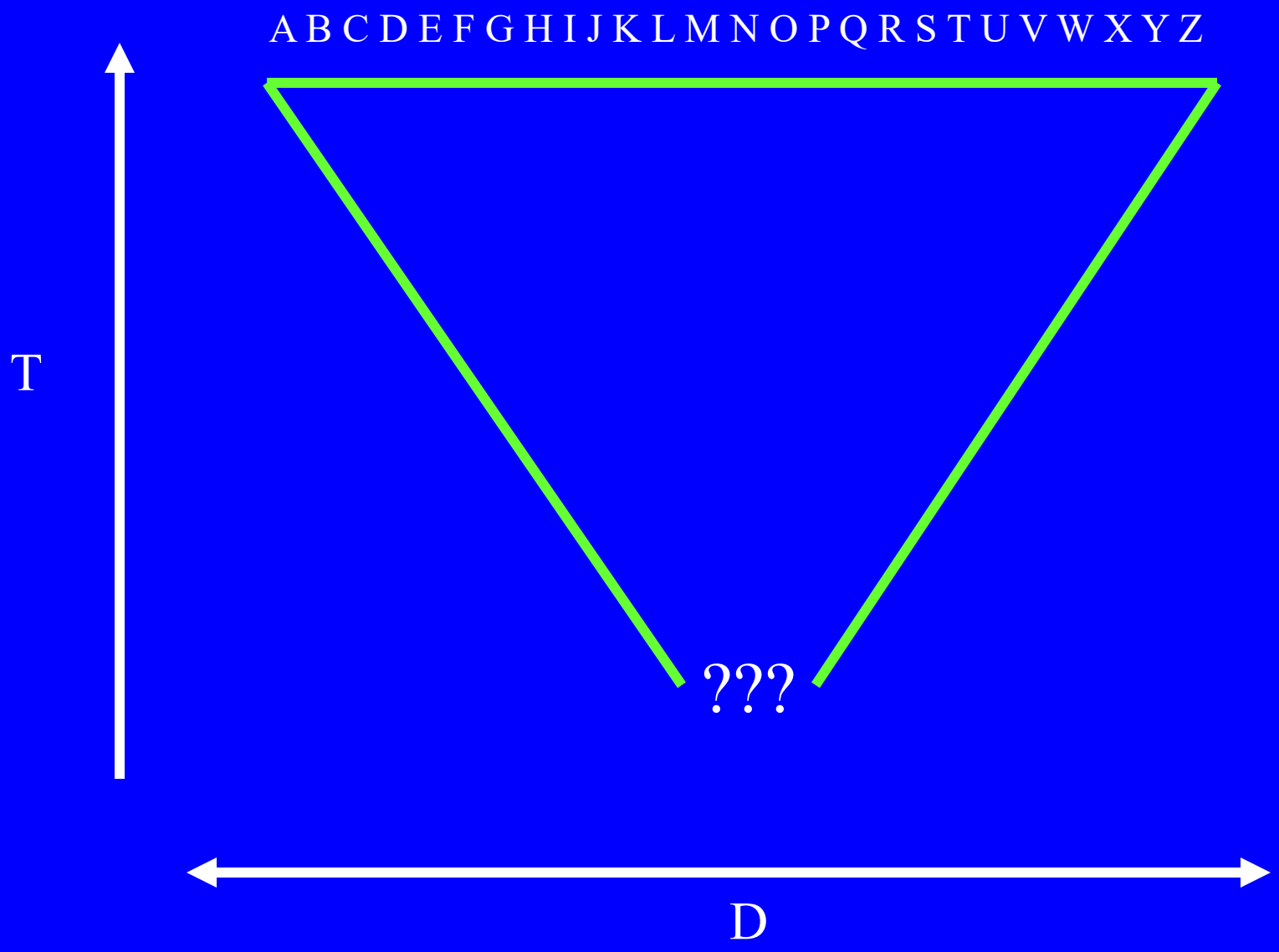
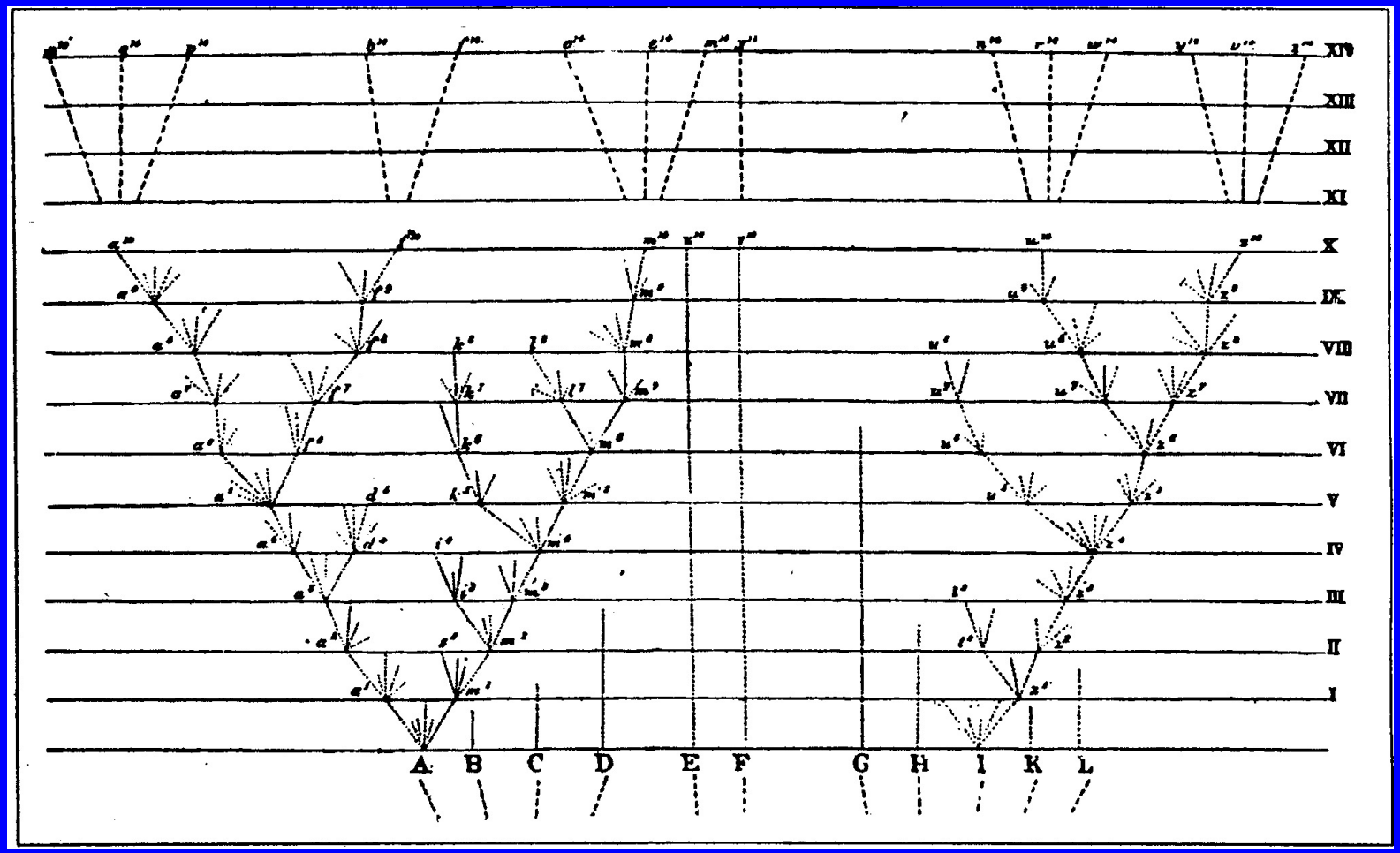


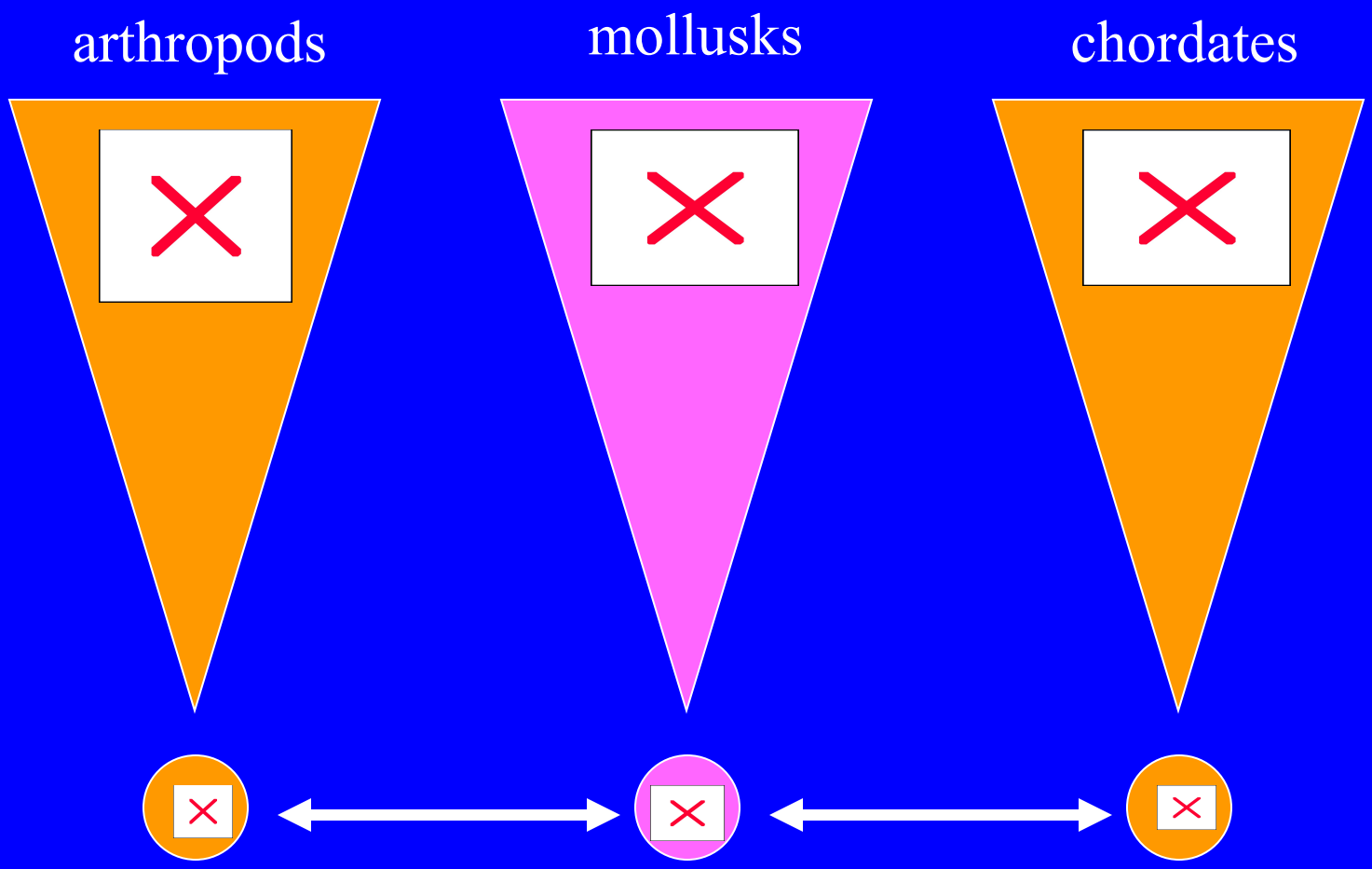
Darwin's (1859, 116) branching diagram



At its furthest extent, Darwin's recursive pattern does not readily converge to a single root.

Here's the problem. At the base of the pattern, animals do not become more similar. In fact, they become increasingly *dissimilar*, displaying what Darwin called "more distinct" (1859, 483) morphologies.

A lobster is not a snail...and neither is a fish



These are fundamentally different architectures (body plans).

The insufficiency of microevolutionary processes to explain macroevolution has become a major theme in current evolutionary biology.

Paleontologist Douglas Erwin, writing in the journal *Evolution and Development* (2000):

"Macroevolution is more than repeated rounds of microevolution."

Geneticist Wallace Arthur (1987, 180) on the unsolved problem of the origin of body plans:

"...one can argue that there is no *direct* evidence for a Darwinian origin of a body plan – black *Biston betularia* certainly do not constitute one! Thus in the end we have to admit that we do not really know how body plans originate."

Geneticist George Miklos (1993, 25) on the unsolved problem of the origin of body plans:

"We can go on examining natural variation at all levels (colouration in beetles is a good example of this pastime), as well as hypothesizing about speciation events in bed bugs, bears and brachiopods until the planet approaches oblivion, but we will only end up with bed bugs, brachiopods, and bears."

Geneticist George Miklos (1993, 25) on the unsolved problem of the origin of body plans:

"None of these body plans will transform into rotifers, roundworms and rhynchocoels. In order to find out why they will not, we need to ask much more interesting questions than those of allelic changes and speciation events."

"Open questions concerning morphological evolution" (Müller & Newman 2003, 5)

Burgess Shale Effect	Why did metazoan body plans arise in a burst?
Homoplasy	Why do similar morphologies arise independently and repeatedly?
Convergence	Why do distantly related lineages produce similar designs?
Homology	Why do building elements organize as fixed body plans and organ forms?
Novelty	How are new elements introduced into existing body plans?
Modularity	Why are design units reused repeatedly?

The problem of macroevolution is unsolved because neo-Darwinism has not incorporated the processes of development into its thinking.

An insightful paper by geneticist Gabriel Dover provide a jumping-off point for considering this.

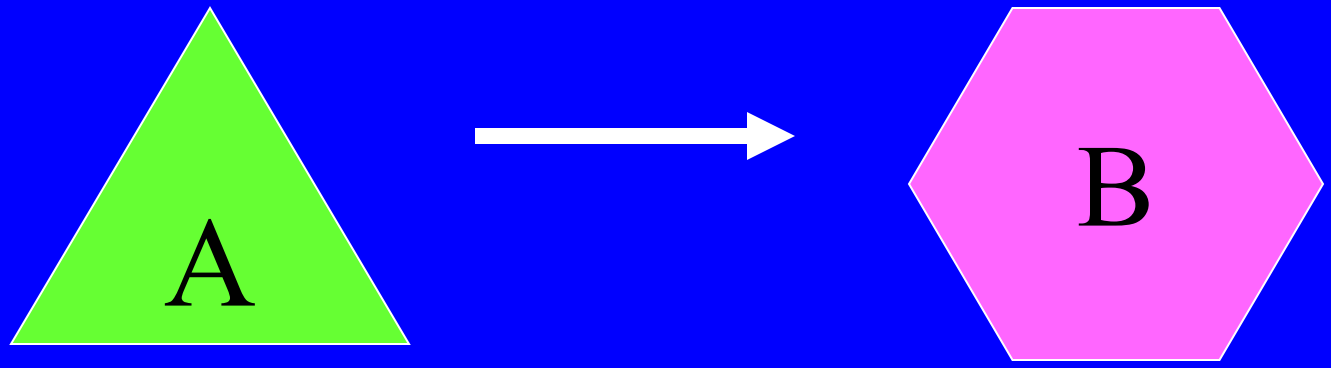
Geneticist Gabriel Dover (1992, 281) on Francis Crick's challenge about evolution:

"At the age of 40 (or thereabouts) I was momentarily reduced to feeling like a 10 year-old novice by Francis Crick in Bronowski's old office at the Salk Institute, where I had gone in the early 1980s to discuss selfish DNA and related concepts."

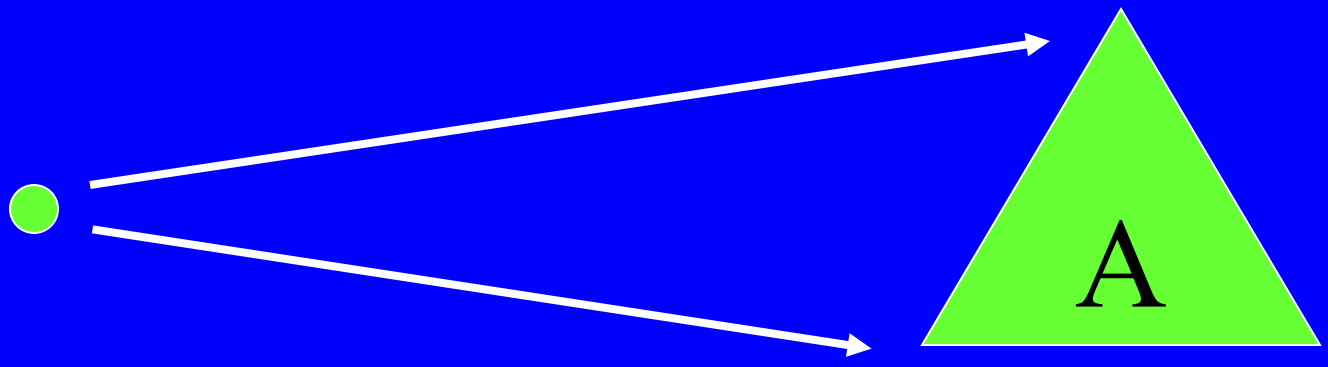
Geneticist Gabriel Dover (1992, 281) on Francis Crick's challenge about evolution:

"Crick challenged me with the statement that
nothing can be said about evolution until we understand
how organisms are put together."

Why do we need to know "how organisms are put together" to understand evolution?

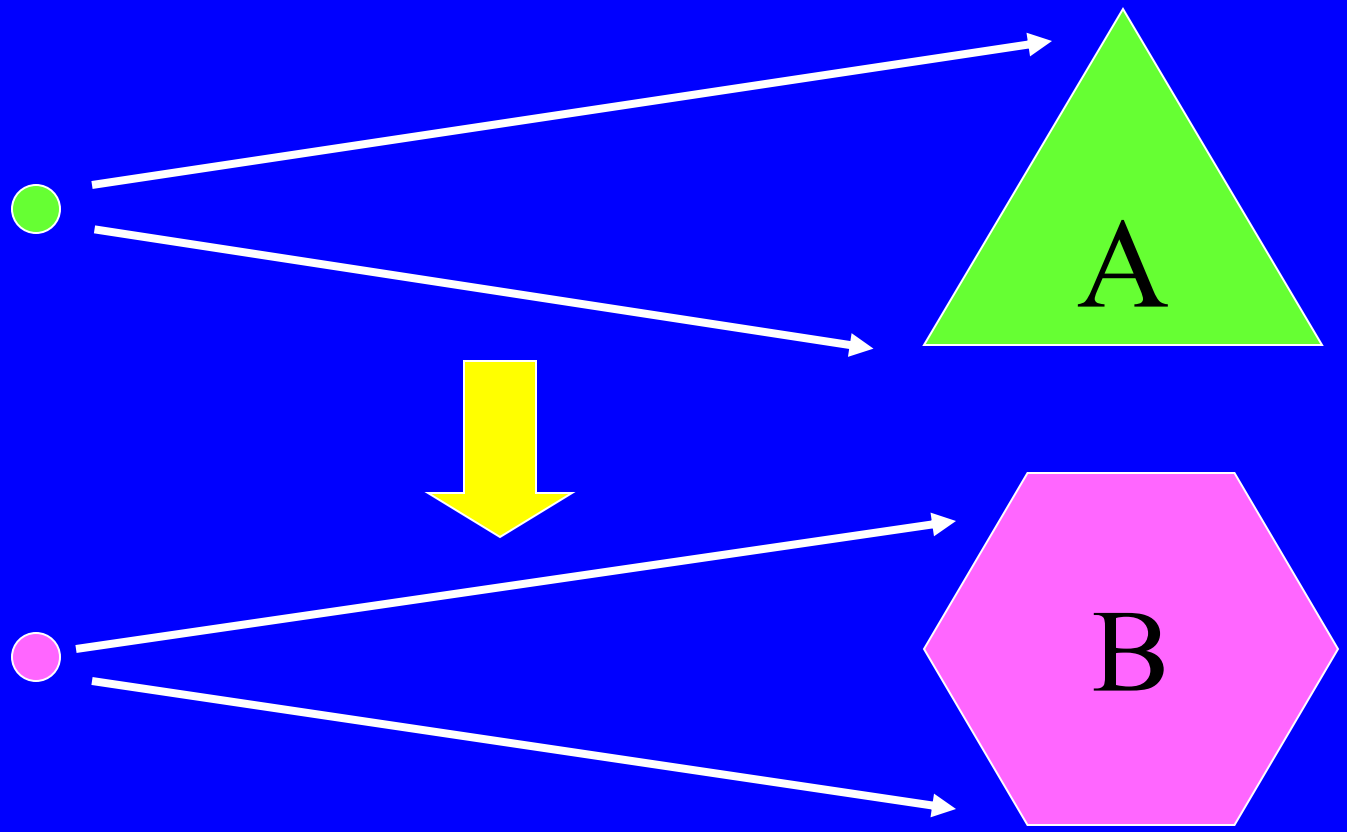


Why do we need to know "how organisms are put together" to understand evolution?



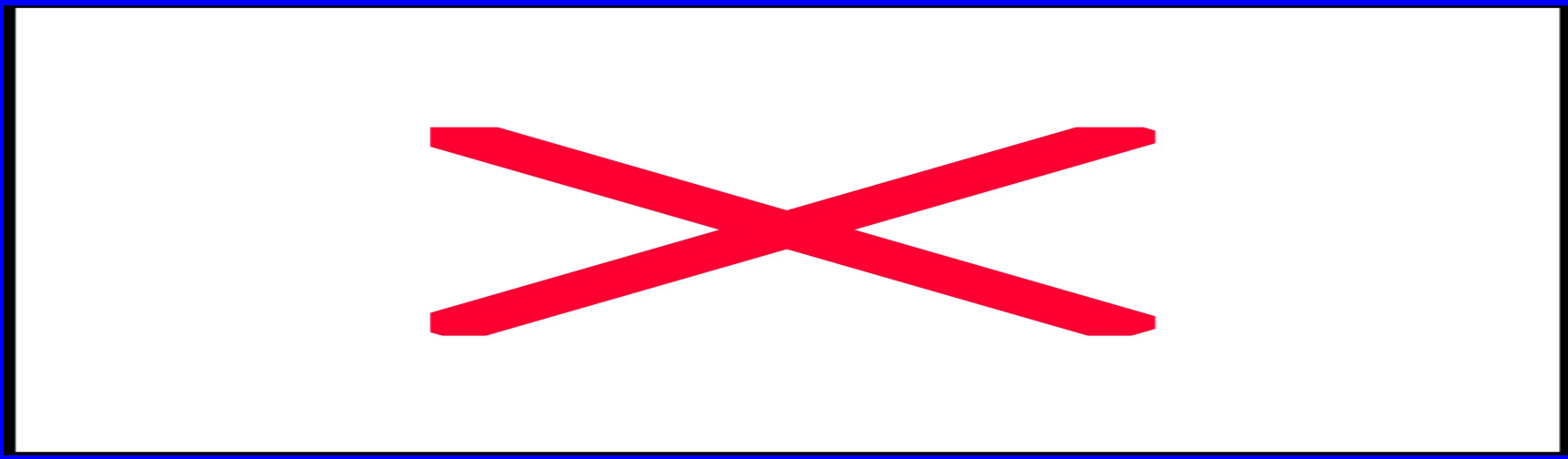
We need first to understand how A is assembled, in *developmental time*.

Why do we need to know "how organisms are put together" to understand evolution?



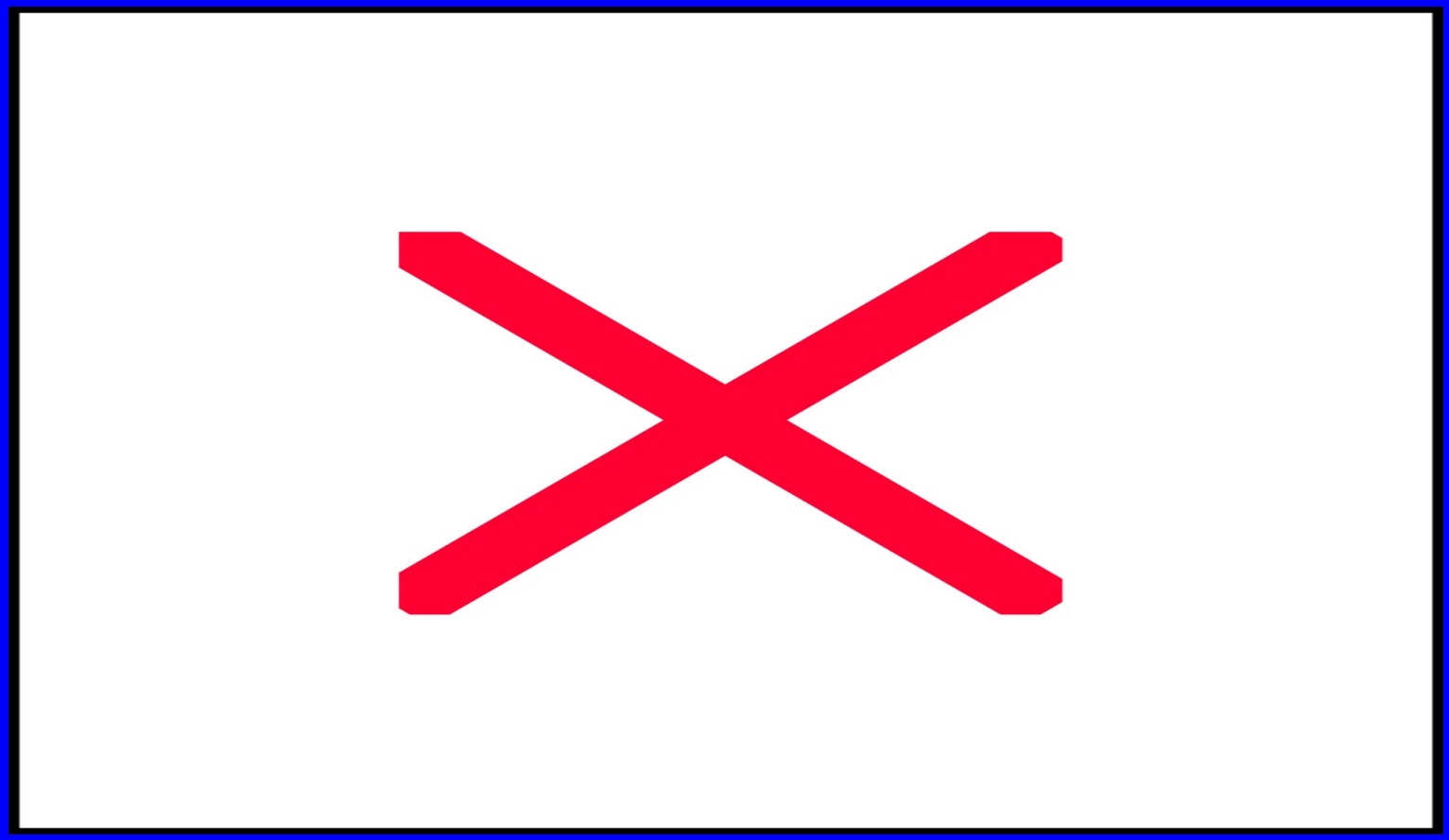
Ascidians (sea squirts)
Genus *Halocynthia*

Tadpole larva of *Halocynthia roretzi*



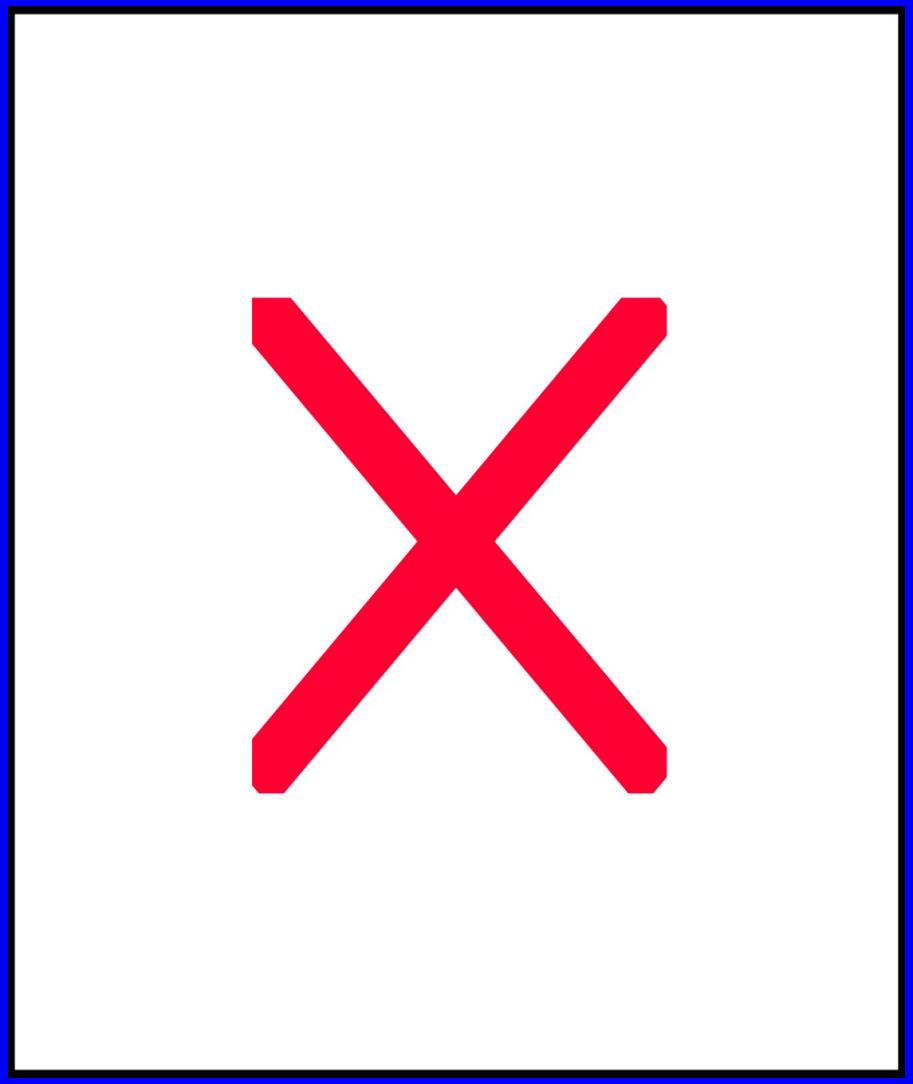
(after Satoh *et al*. 1990)

Restriction of developmental fate during early cleavage stages in ascidians

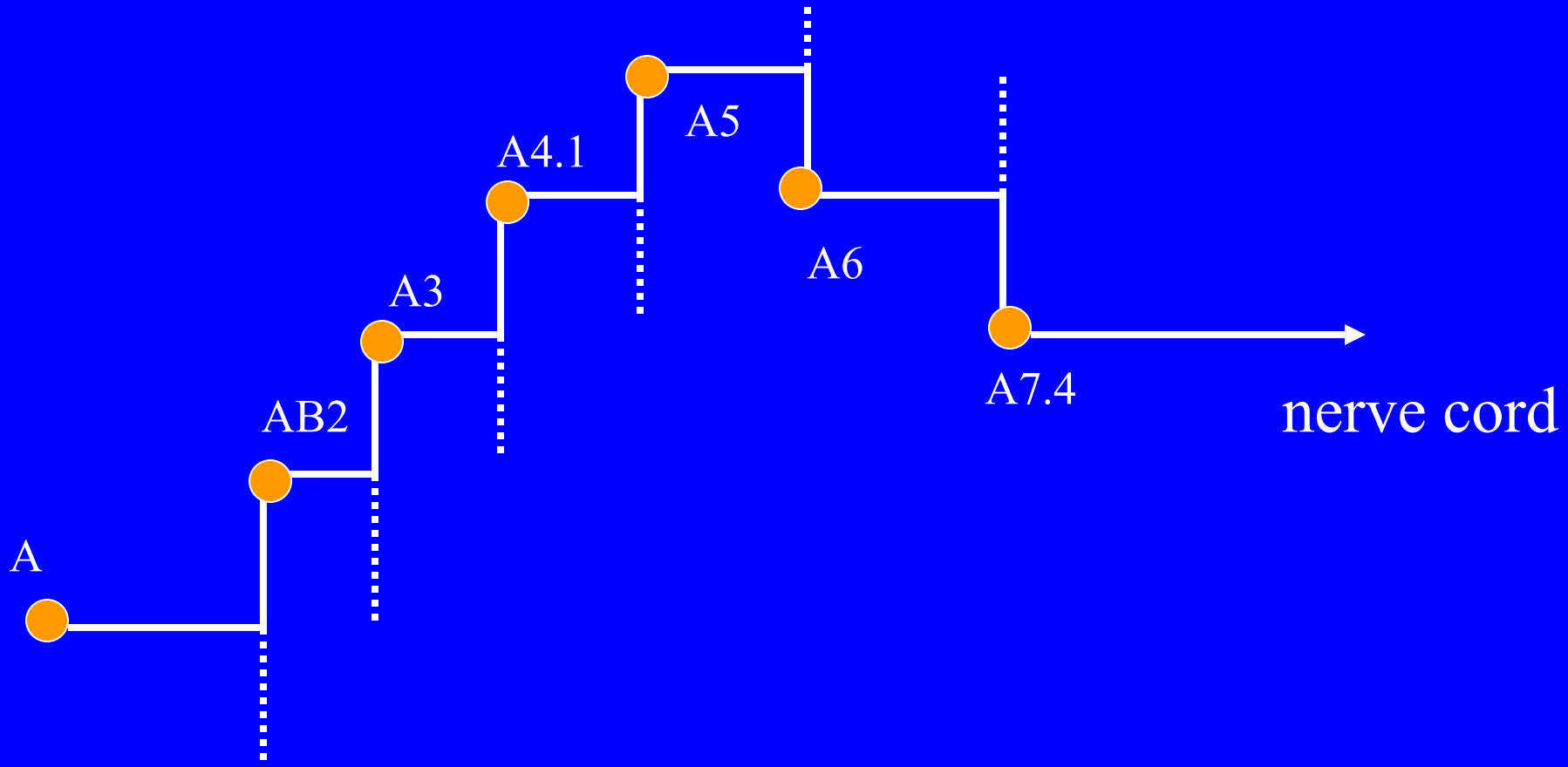


(from Nishida 1997, 362)

Early cell lineages in the ascidian *H. roretzi*

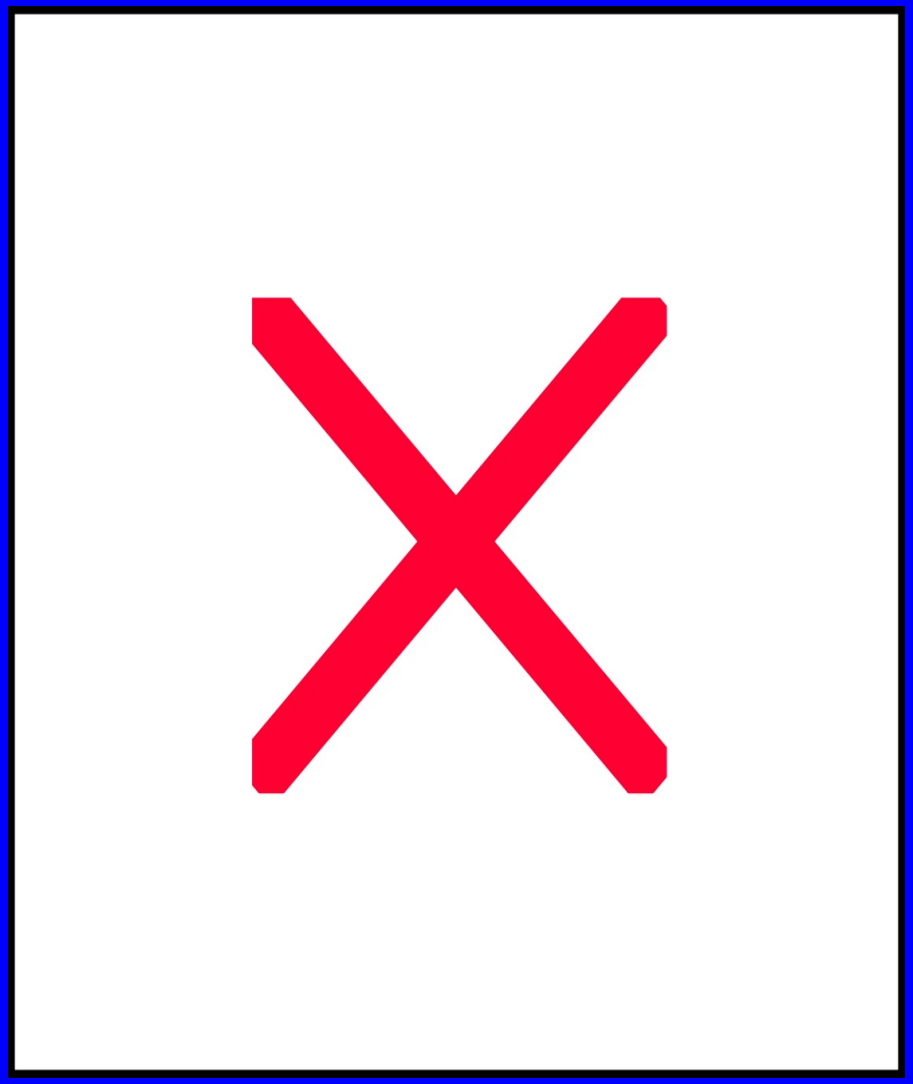


(from Nishida 1997, 361)



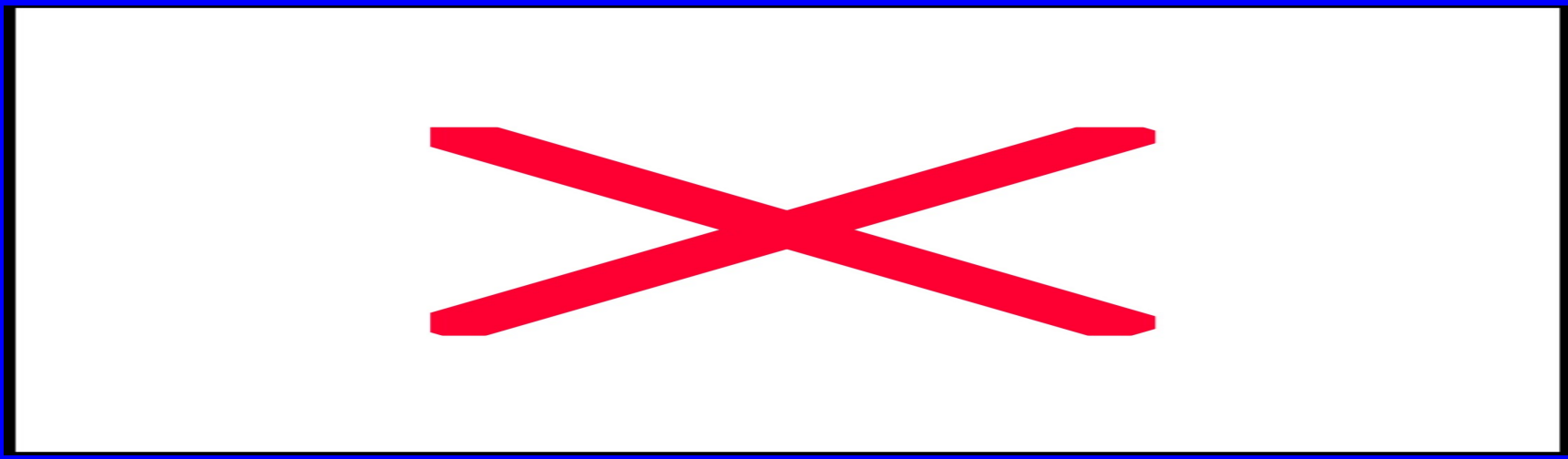
If development is interrupted at any of these stages, the embryo will die.

Early cell lineages in the ascidian *H. roretzi*



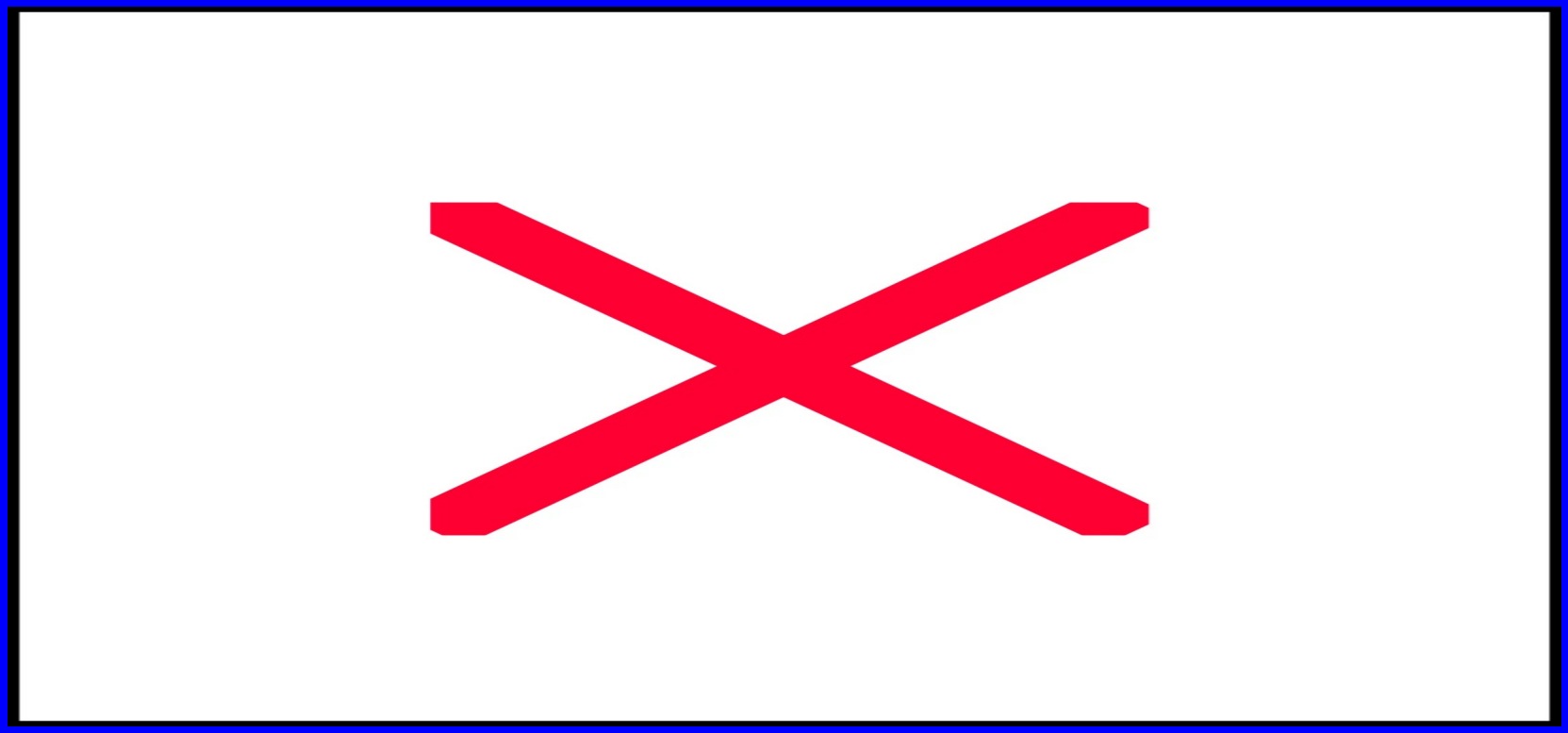
(from Nishida 1997, 361)

Tadpole larva of *Halocynthia roretzi*



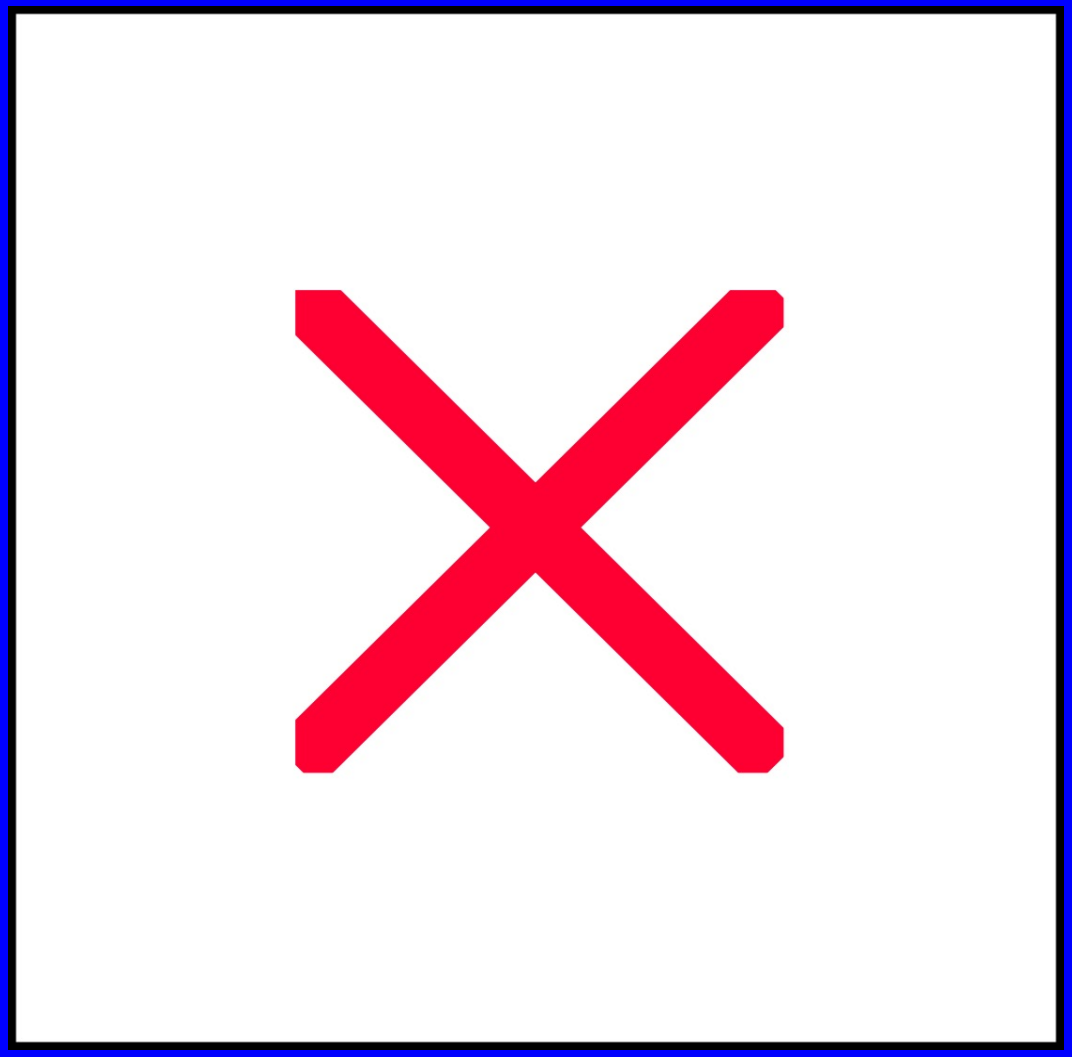
(after Satoh *et al*. 1990)

Adult morphology of *Caenorhabditis elegans*



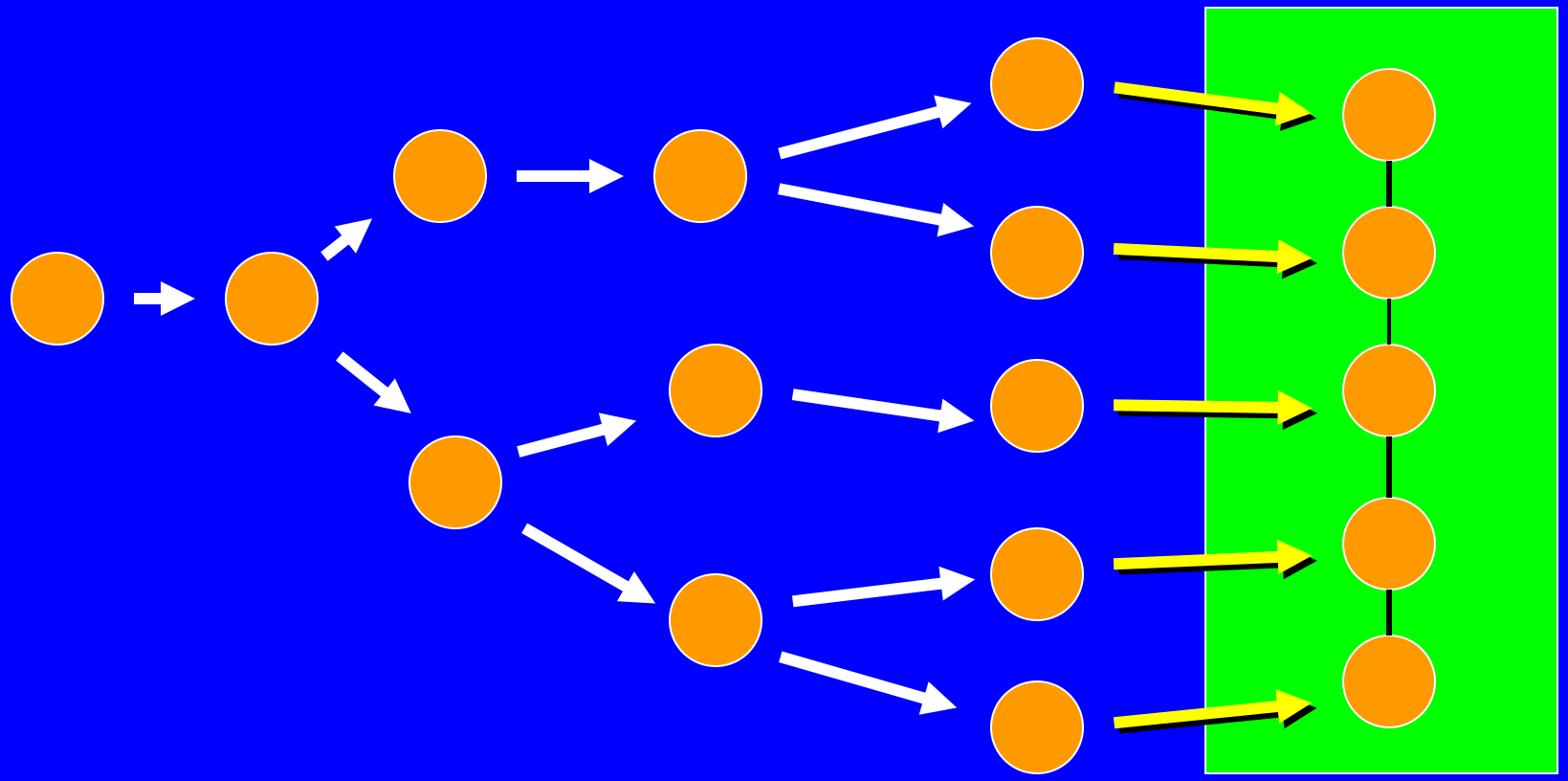
(figure after Hodgkin 1987, 135)

The early cell lineage of *Caenorhabditis elegans*



(figure after Schnabel 1997, 342)

Can natural selection build complex developmental networks?



Natural selection only "sees" function

The requirements of natural selection:

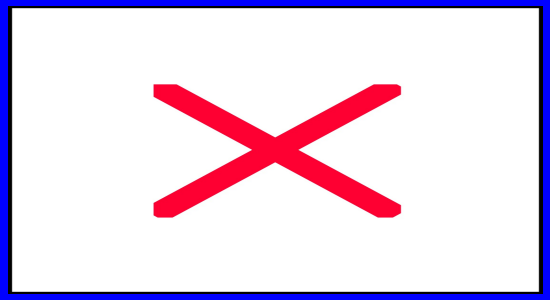
- variation
- selection
- heredity

Bottom line: if you cannot leave viable offspring, then as far as natural selection is concerned, you're an evolutionary dead end.

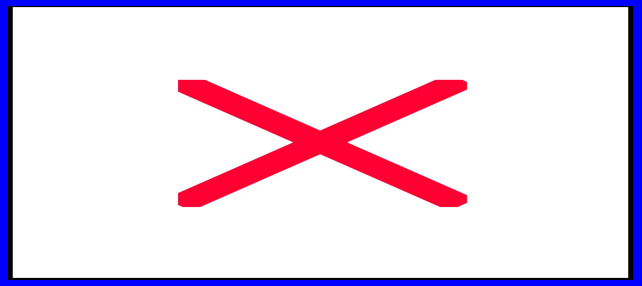
So how do organisms solve this problem – that is, obtaining the instructions to build an embryo?

Answer:

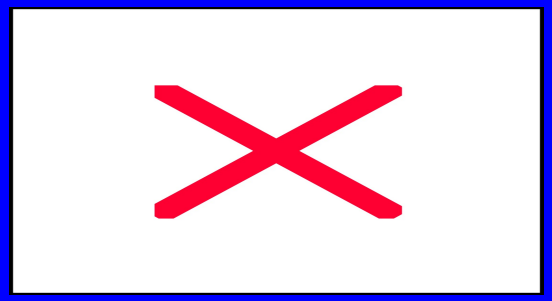
They have parents.



Mom



Oocyte



Junior

Rupert Riedl (1978, 219-20) on the paradox of "teleological evolution":

"If these 'diagrams of organisms' represented functional ancestors they would prove the paradox of teleological evolution. For their parts always strive towards functions, without being able to possess them during their formation."

Rupert Riedl (1978, 219-20) on the paradox of "teleological evolution":

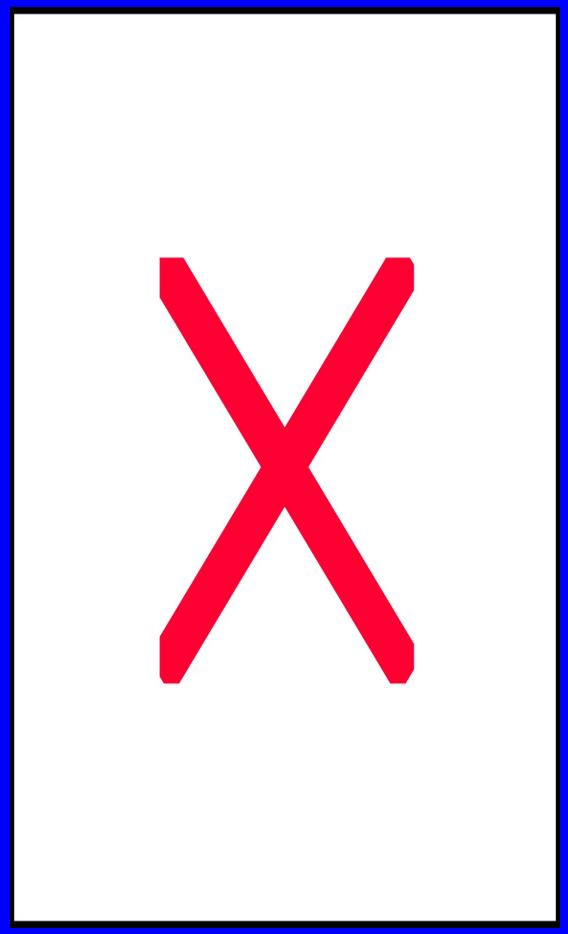
"Like orderly piles of bricks or building timber, they do not yet have a function. In the same way scaffolding may indicate the shape of the future building, though it would fail any test of thermal or noise insulation, not to mention habitability."

Question: Why is "teleological evolution" a "paradox"?

Here is where the possibility of intelligent design comes into play – along with some thorny philosophical issues.

Is it *possible* that life was intelligently designed?

The disappearance of a possible cause



"The Darwinian revolution was as much concerned with the promotion of a particular view of science as it was with the introduction of a theory on the transmutation of species."

David Hull, "Darwin and the nature of science" (1983, p. 65)

natural causes

and

intelligent causes

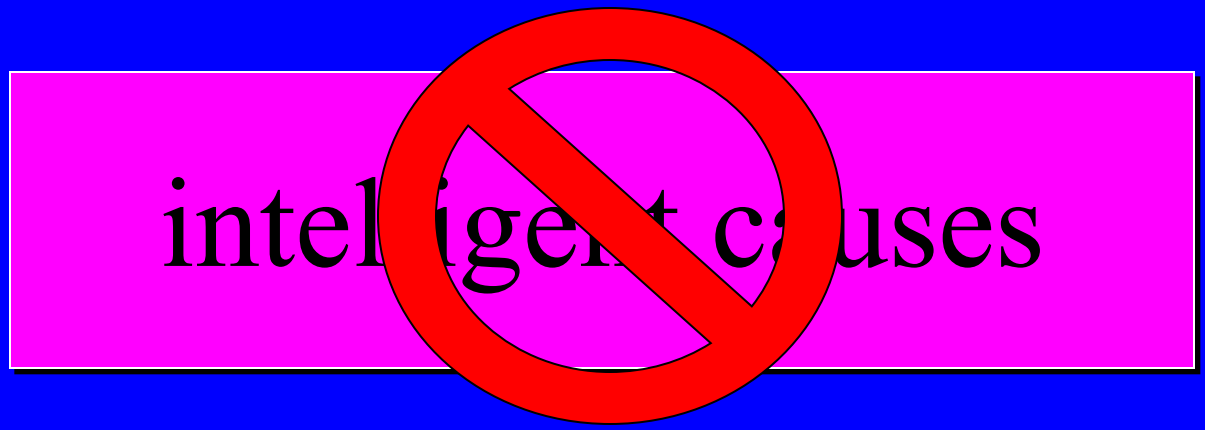
The Rule of Methodological Naturalism

"The statements of science must invoke only natural things and processes."

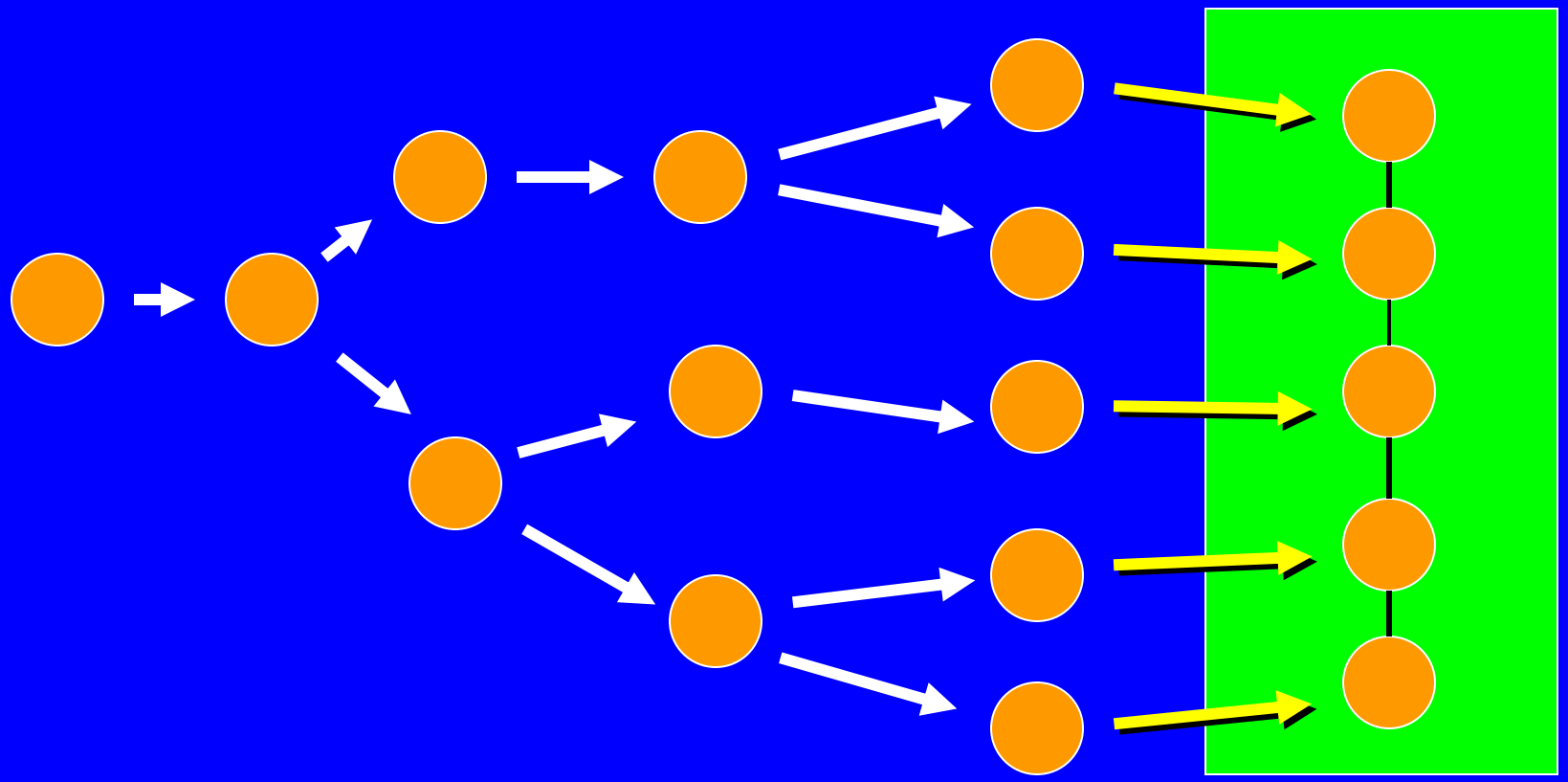
National Academy of Sciences
(Donald Kennedy *et al*., 1998)

natural causes

and



But what if higher-level functions and structures are real...and genuinely irreducible?



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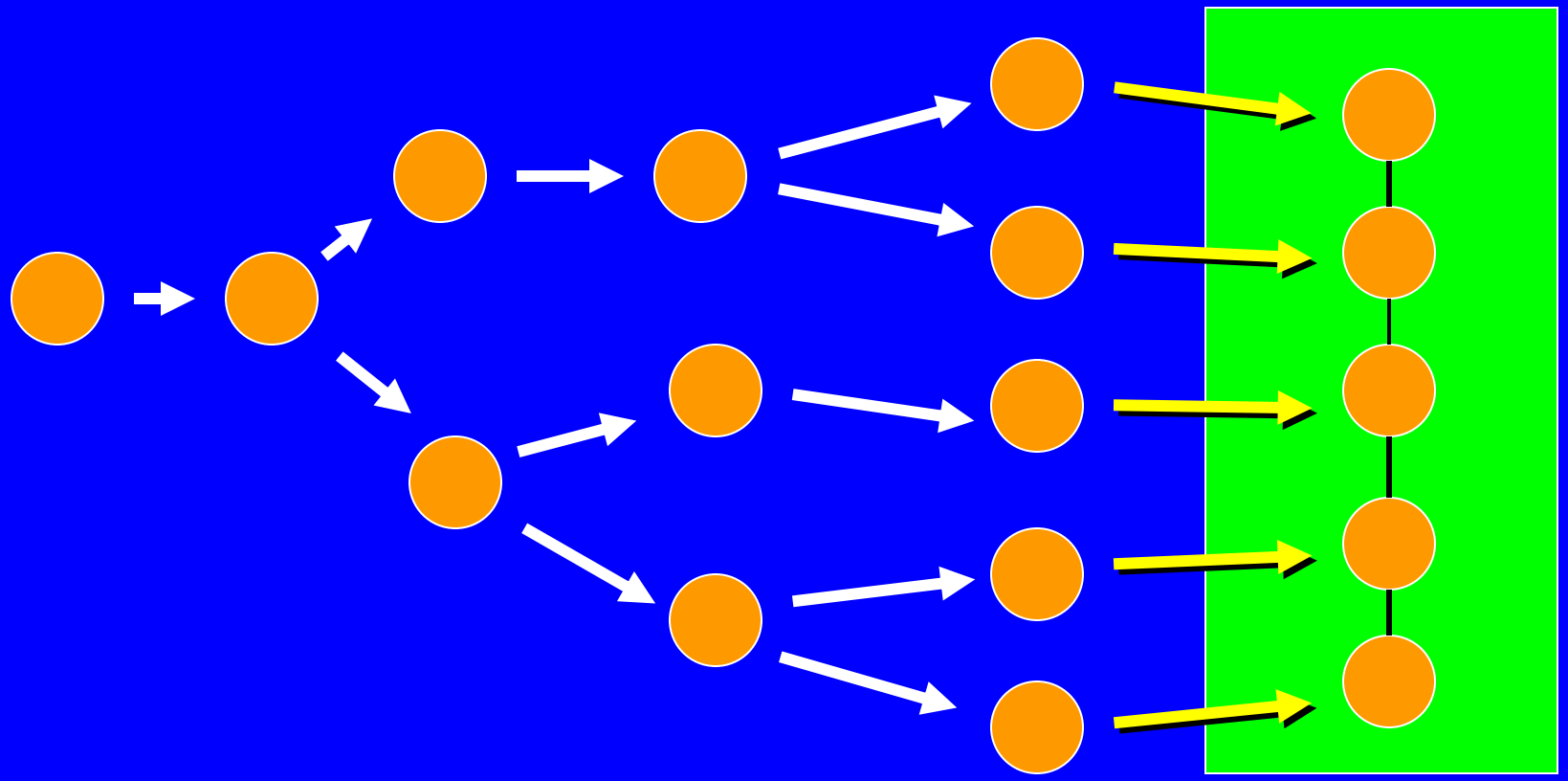
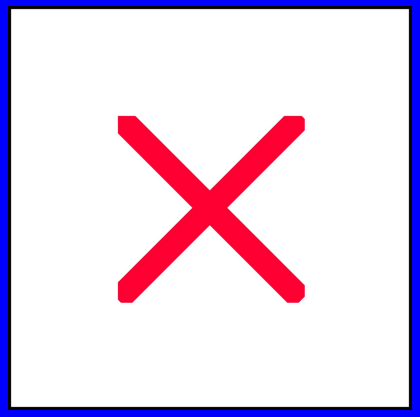


Intelligence can forsee an outcome, and actualize it.

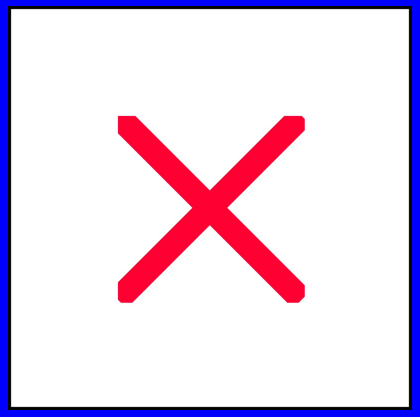
3. What might design contribute to these puzzles?

The significance of modularity

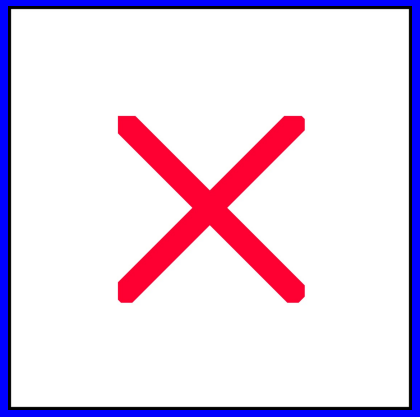
Three classically non-homologous eyes



Vertebrates



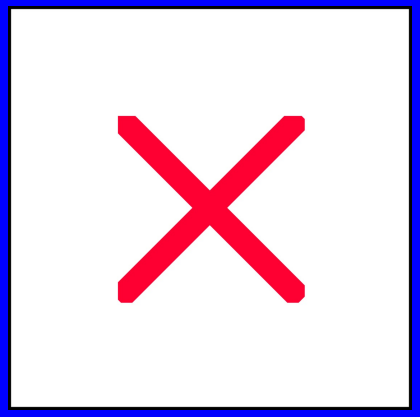
Molluscs



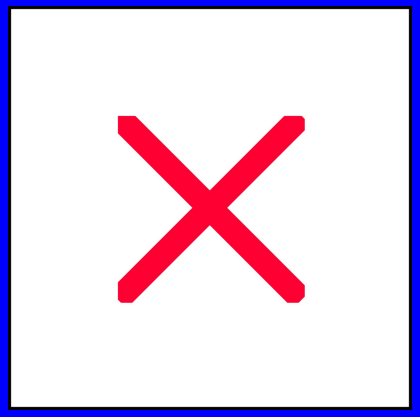
Arthropods

The neo-Darwinian expectation was that eyes such as these, separated by hundreds of millions of years of evolution, would have very different genetic constituents.

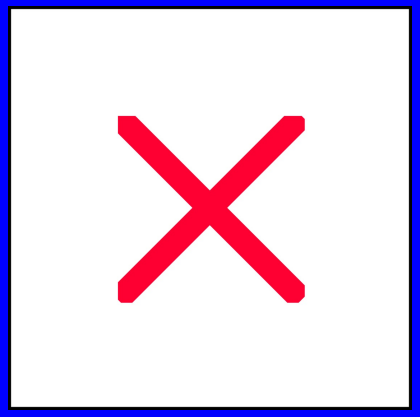
Three classically non-homologous eyes



Vertebrates



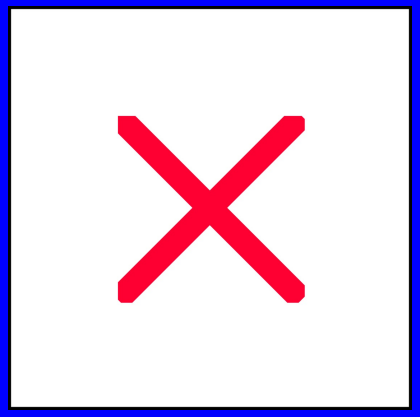
Molluscs



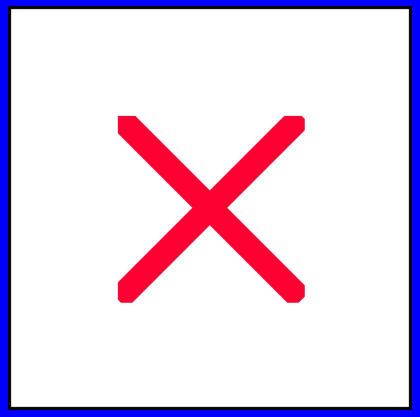
Arthropods

But the development of each of these eyes is regulated by the same so-called "master regulator" gene, Pax-6.

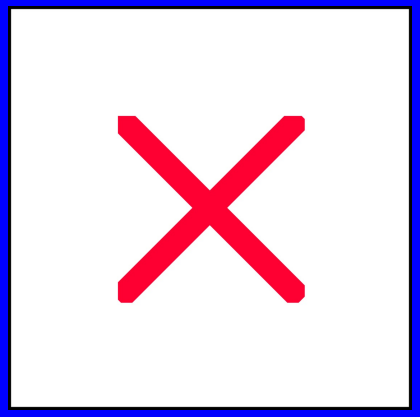
Three classically non-homologous eyes



Vertebrates



Molluscs



Arthropods

Indeed, the homologue of Pax-6 from a mouse can be expressed in a fly – and it works just fine.

The modularity of homeobox genes, as illustrated by cross-phylum rescue or substitution experiments:

Gallus to *Drosophila* (Hunter & Kenyon 1995)

Drosophila to *C. elegans* (Lutz et al. 1996)

Loligo to *Drosophila* (Tomarev et al. 1997)

Homo to *Drosophila* (Rincon-Limas et al. 1999)

Results like these are usually interpreted to indicate the deep phylogenetic conservation of key embryonic regulators.

But such interpretations raise many paradoxes (see Erwin & Davidson 2002) – e.g., what sort of complex eye could be ancestral to arthropod compound eyes *and* two classically non-homologous camera eyes?

Let’s try a design-theoretic thought experiment – one that takes the reality of higher levels seriously.

Taking a lexicon from the Gettysburg Address:

"...that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion -- that we here highly resolve that these dead shall not have died in vain -- that this nation, under God, shall have a new birth of freedom -- and that the government of the people, by the people, for the people, shall not perish from the earth."

Taking a lexicon from the Gettysburg Address:

a
and
birth
by
cause
dead
devotion
died
earth
for
freedom
from
full
gave
God
government
have
here
highly
honored
in
increased
last
measure
nation
new
not
of
people
perish
resolve
shall
take
that
the
these
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this
to
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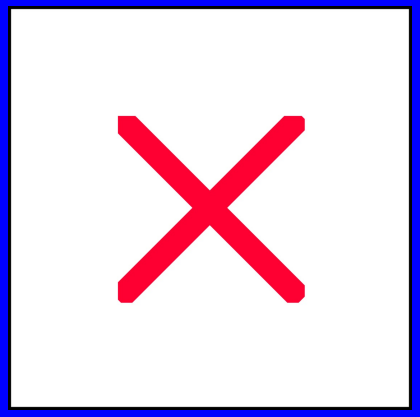
we
which

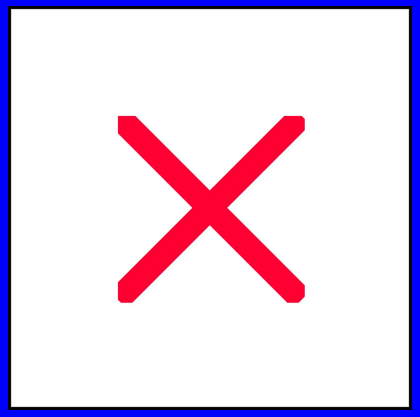
Taking a lexicon from the Gettysburg Address...*and writing a very different text -- an anarchist's manifesto:*

"...by this we highly resolve that we shall have freedom from this nation -- that devotion shall perish. These people honored the last government, in vain. The dead increased. Measure that full devotion! The earth under here gave these people birth, not a dead God, and from that they shall take their new cause, for which people have not died."

Three classically non-homologous eyes



Vertebrates



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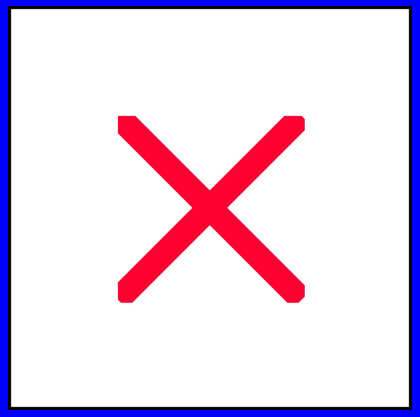
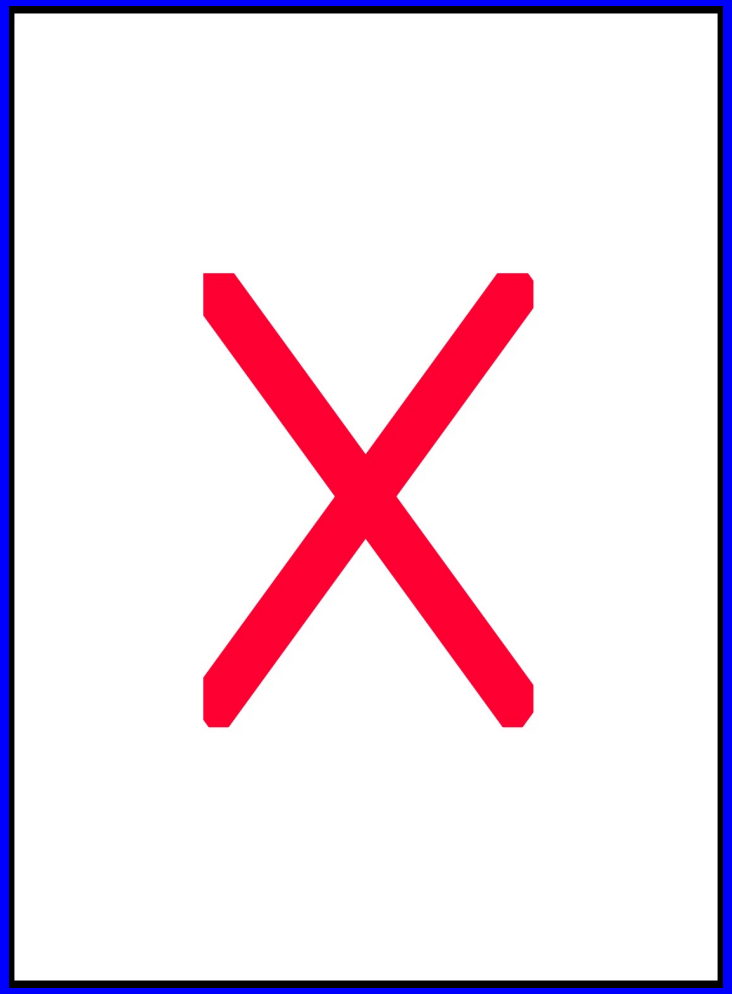
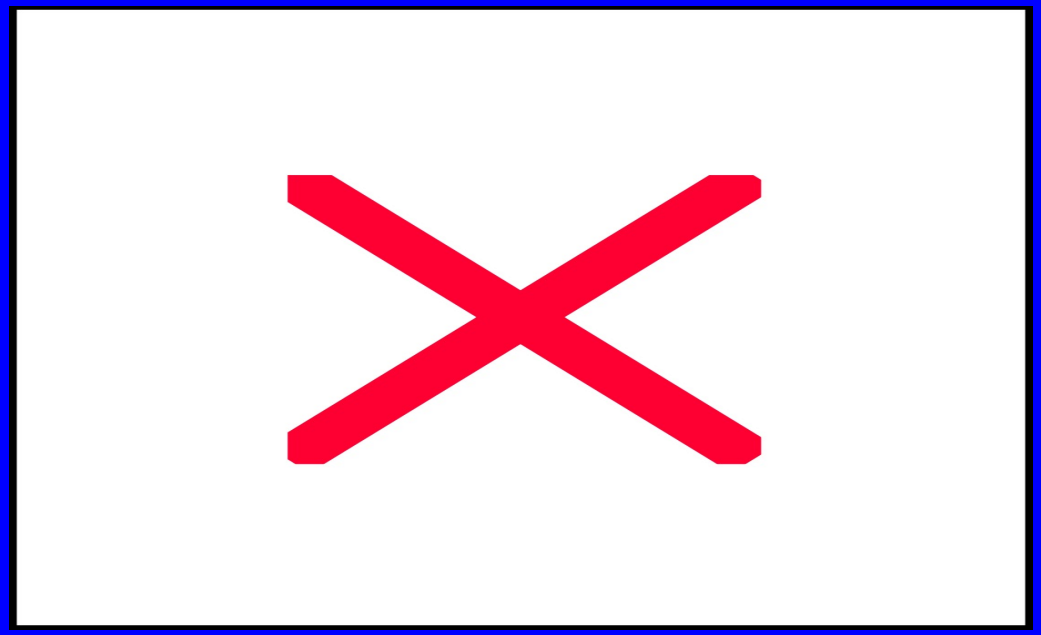


Arthropods

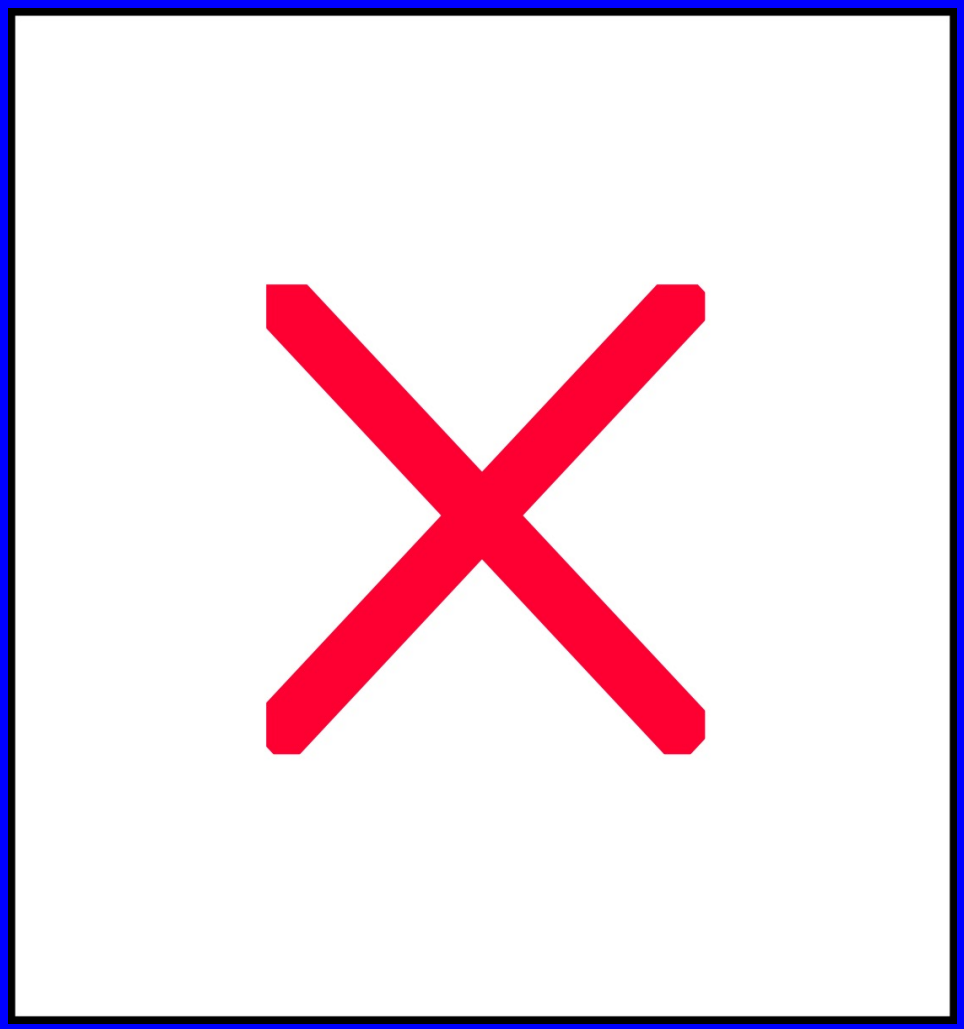
Might the modularity of Pax-6 (and other discoveries unexpected by neo-Darwinism) reflect the intelligent use of lower-level units for very different higher-level structures?

Jun-Yuan Chen *et al*., "Small Bilaterian Fossils from 40 to 55 Million Years Before the Cambrian," *Science* 305 (2004):218-222.





18s (small subunit) ribosomal RNA



(figure from Ueda-Nishimura and Mikata 2000)