Biological Evolution
What is the evidence for it?

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2010

Evolution

What is it?

Evolution is a scientific theory that includes these concepts:

- Living organisms change gradually from generation to generation
- When change has accumulated in a species so that two populations cannot breed, two new species have been formed
- Formation of the diversity and complexity of today's species has required a very long time
- Similarities among all living organisms indicate they all arose from a common ancestor
- The species living at any moment have been determined by adaptation and selection

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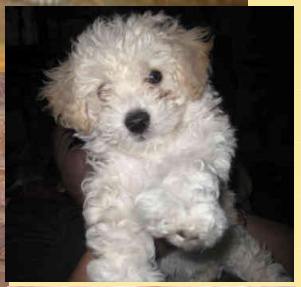
Change occurs

Living organisms change from one generation to the next

All dogs descended from the wolf over the last 15,000 years



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Change occurs

Broccoli, cauliflower, kohlrabi, kale, Brussel sprouts, collard greens, romanescu, ordinary cabbage and other varieties have all been bred from wild cabbage

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Selection

In order for change to accumulate, something has to select one trait over others

For dogs and cabbages, selection is done by humans

Does selection occur in nature?

Almost all organisms produce more offspring than can survive

The offspring that have some variation that helps survival are the ones that survive

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Isolation

Change plus selection over time produces large change

But does it produce new species?

A third factor, isolation is required to prevent interbreeding

In human-performed breeding isolation is rigidly enforced by the breeder

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Isolation

The Galapagos Islands where Darwin first gathered evidence for speciation

Isolation can be provided by islands, rivers, mountains, migration and other natural circumstances

Evolution

It's obvious

Change +

Selection +

Isolation =

Evolution

Evolution

Selection

The Peppered Moth lives in England
Before the industrial revolution, almost all peppered moths were light colored
A few decades after the industrial revolution, almost all the moths were dark

Evolution

Selection

The soot from the use of coal to power the factories darkened the bark of trees and killed the lichens on them

Bird predators were able to see the light moths better and ate them

The dark moths, who had been very visible and were commonly eaten, now were harder to see and flourished

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Speciation

A species is a collection of animals that can breed with one another

Development of a new species requires isolation and selection pressure

Have we ever observed the creation of a new species?

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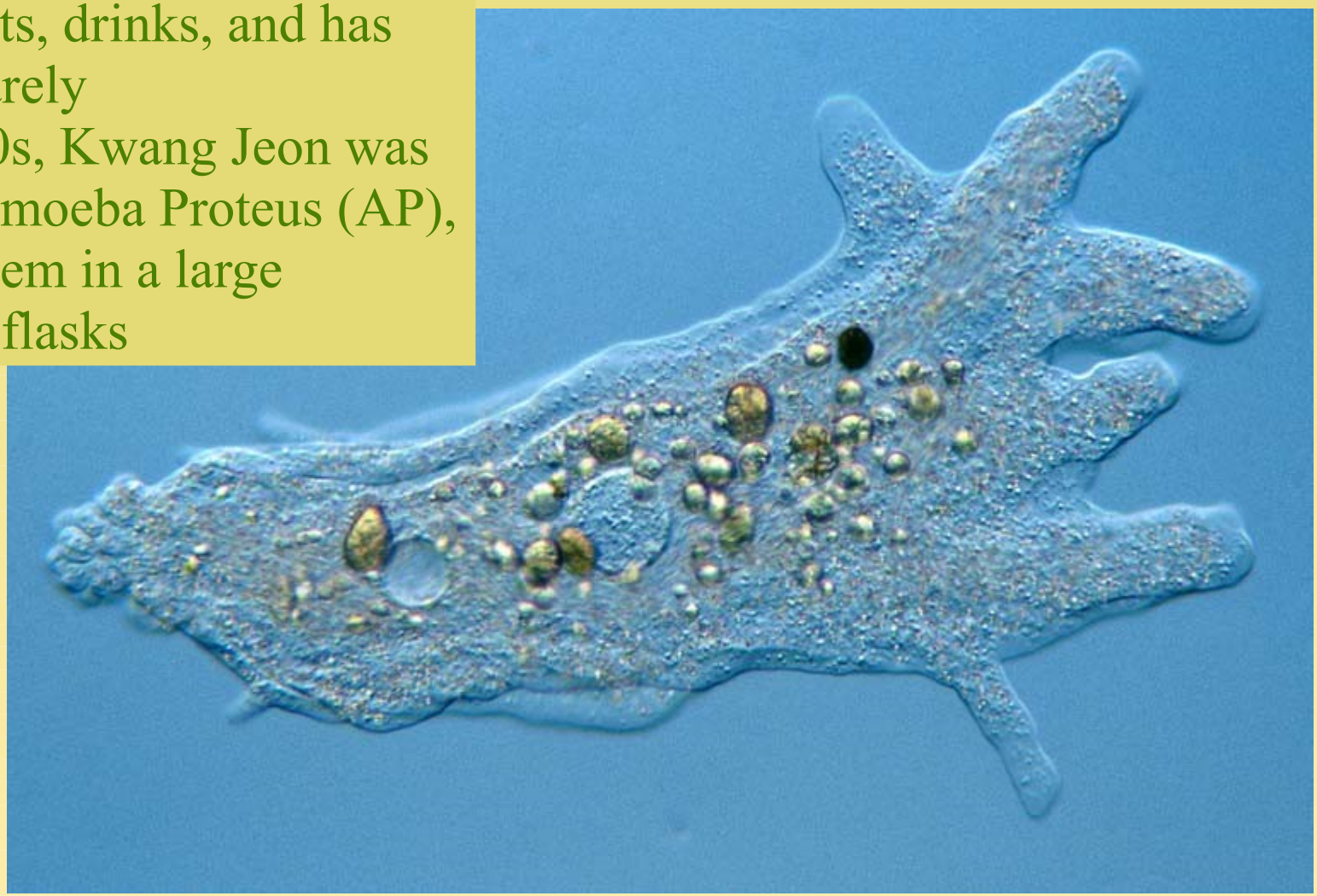
Speciation

Amoeba Proteus is a eukaryotic cell that eats, drinks, and has sex very rarely

In the 1960s, Kwang Jeon was studying Amoeba Proteus (AP), growing them in a large number of flasks



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Speciation

The AP had all been derived from a single ancestor

A few of the flasks became infected with an unknown bacteria

In one of these flasks, a very few AP survived with bacteria inside their bodies

When an antibiotic was used to cure some of the surviving AP, they died

Uninfected AP tolerated the antibiotic very well

The surviving bacteria had become dependent on the bacteria

Evolution

Speciation

Before the infection the AP had two genes for different versions of an enzyme, S-adenosylmethionine synthetase, but only one was active

The bacteria inhibited the active gene

A mutation occurred in one or a few AP that turned on the second gene if and only if the bacteria were present

Thus, a genetically distinct, completely new species of Amoeba Proteus arose

Was this event a one-of-a-kind?

Evolution

Speciation

Fruit flies breed rapidly and are easy to keep in a lab

W. Rice and G.W. Salt built a maze for the flies

In the maze, the flies had to choose wet or dry, dark or light

The flies coming out of two exits were kept separate and allowed to breed

The separation was repeated for thirty-five generations and resulted in reproductively isolated species

Evolution

Speciation

Diane Dodd fed fruit fly groups either starch or maltose

After only eight generations, the flies were reproductively isolated into species

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Speciation

What about observing the creation of a new species in the wild?

It's not possible to get the kind of detailed information that one gets in the lab because:

- Cannot isolate groups
- Cannot observe groups systematically
- Requires very long time
- Don't know where to look

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Speciation

We have some examples of partially nonbreeding species

Horse

Mule

Donkey

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Fossils

A fossil is a portion of rock in which the mineralization was affected by the remains of an organism and thus reflects some features of the organism

The fossil record sheds considerable light on the historical course of evolution, but it is not necessary to confirm evolution's role in earth's development

Several objections to the fossil record are sometimes made

Objections include

- The Cambrian Explosion
- Missing links

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The Cambrian Explosion

Rocks older than the Cambrian period (~500 Mya) contain many fewer fossils than do younger rocks

This is sometimes presented as proof that the Cambrian organisms did not evolve from more primitive organisms

The transition from few to many occurred in a mere 20 million years

In fact, we have evidence for a diversity of PreCambrian organisms

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The Cambrian Explosion

Organisms that have no skeletons leave no fossils

The Cambrian period is simply the one in which some organisms developed skeletons

Very few worm fossils are known from any period, early or late

Ample evidence for one-celled animals such as bacteria go back hundreds of millions of years before the Cambrian

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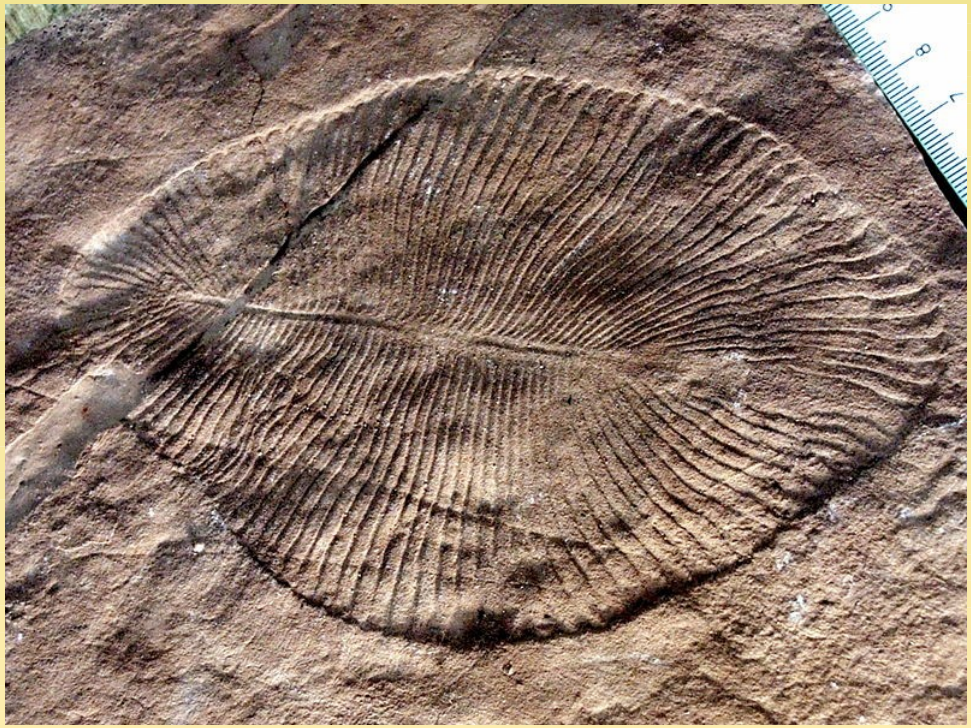
The Cambrian Explosion

Nonfossil evidence for multicelled PreCambrian organisms is plentiful

In fact, some fossils from earlier times do exist

Ediacaran fossil 635-542 Mya



Cambrian fossil 542-488 Mya

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Missing links

We do not have fossils for every type of creature that ever lived

In some cases, we have no rocks of a particular age due to erosion and plate tectonics

The conditions for fossil formation are stringent. The remains must survive a very long time before they are fossilized

Consider two cases

- Dinosaurs to birds
- Primitive primates to humans

Evolution

Dinosaurs to birds

Dinosaurs are the ancestors of birds was suggested by T H Huxley in 1868

Before the 1970s, bird-like dinosaur fossils were rare

The first Archaeopteryx was found in 1861

The Berlin Specimen (shown here) was originally traded for a cow. Note the long tail

The specimens vary (continuous evolution

Jurassic, 150-145 Mya

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Dinosaurs to birds

More recently other transitional fossils have been found

Many of them are more dinosaur like. Some of them are more birdlike

Overall, they form a good outline of the dinosaur to bird transition

Evolution

Dinosaurs to birds

The development of birds from dinosaur-like ancestors is increasingly well documented by the fossil record. Rather than missing-links, we have a record of several stages of the transition

Microraptor, ~120 Mya

Alvarezsauroid, ~160 Mya

until the 1990s," says Philip Currie, a paleontologist at the University of Alberta in Edmonton, Canada. As specimens turned up in Asia, Europe, and North America, debate raged over whether they represented dinosaurs or

birdlike features seen in later alvarezsauroids such as fused wrist bones, a backward-facing pubis, or a crest near the top of the shinbone.

Birds of a feather. A new avianlike alvarezsauroid (*below*) predates the first bird, *Archaeopteryx*—powerful evidence that birds arose from dinosaurs. Fossilized pigment organelles reveal the true colors of *Sinosauropteryx* (*left*).

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Primitive Primates to Human

For a long time we had very few transitional forms between primitive primates and humans

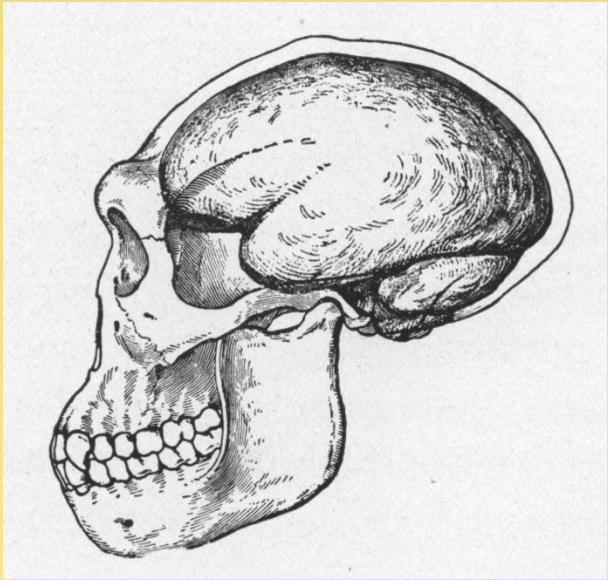
Java Man, 1891

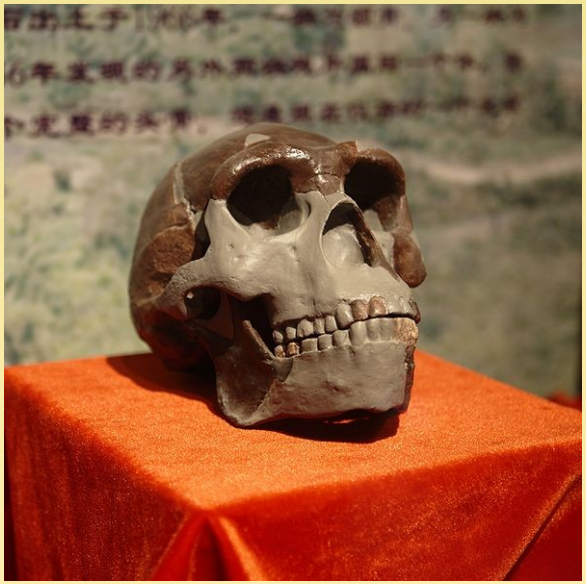
Peking Man, 1927

Stood upright, used fire and tools

Less than 1 Mya

Why none older?





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Primitive Primates to Human

None were older because the explorers were looking in the wrong place—Asia

Go to Africa, in particular, the Rift Valley

Now we have

> 6 Mya	10
4-6 Mya	1
3-4 Mya	10
2-3 Mya	8
1-2 Mya	25
0.1-1 Mya	31
50-100,000	16

However,

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Primitive Primates to Human

However, some people who look at this wealth of fossil hominids just see more missing links

Evolution

Age of the Earth

Evolution takes time. How old is the earth?

4.54 Billion years

How do we know?

- Radiometric dating
- Geologic processes

The Acasta Gneiss in northern Canada: 4.03 Bya

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Radiometric dating

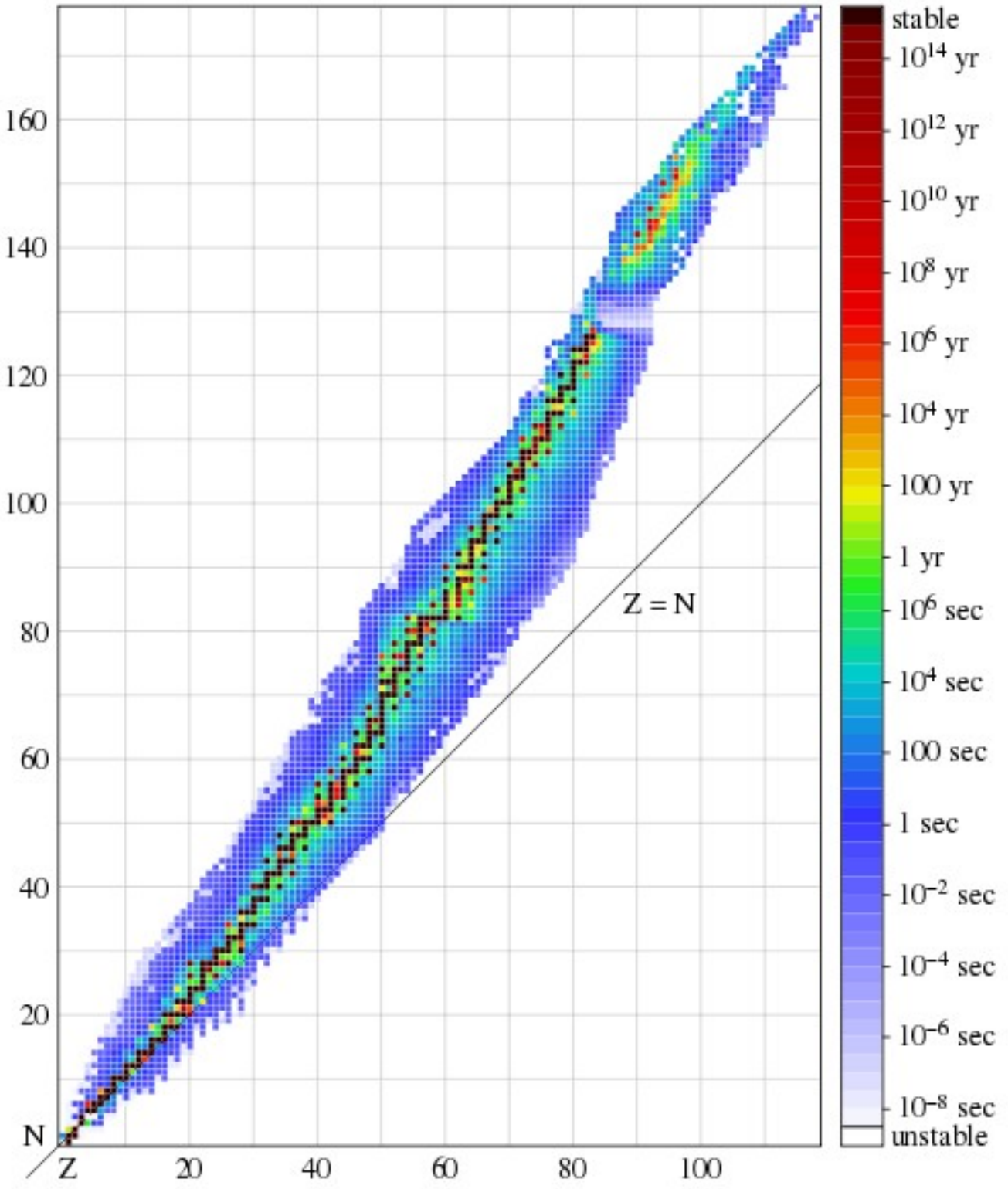
All radioactive elements decay at a constant rate. The half-life is how long it takes for half the atomic nuclei to decay

128 plus half-life = 64

64 plus half-life = 32

32 plus half-life = 16

And so forth, on average



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Radiometric dating

$^{238}U \rightarrow ^{234}Th \rightarrow ^{234}Pa \rightarrow ^{234}U \rightarrow ^{230}Th \rightarrow ^{226}Ra \rightarrow ^{222}Rn \rightarrow$

$^{218}Po \rightarrow ^{214}Pb \rightarrow ^{214}Bi \rightarrow ^{214}Po \rightarrow ^{210}Pb \rightarrow ^{210}Bi \rightarrow ^{210}Po \rightarrow$

^{206}Pb (stable)

$t_{1/2}$ ($^{238}U \rightarrow ^{206}Pb$) = 4.468 By

Evolution

Radiometric dating

^{238}U decays into ^{206}Pb

If the amount of each isotope is known when the rock solidifies, the amount of each today indicates the age of the rock

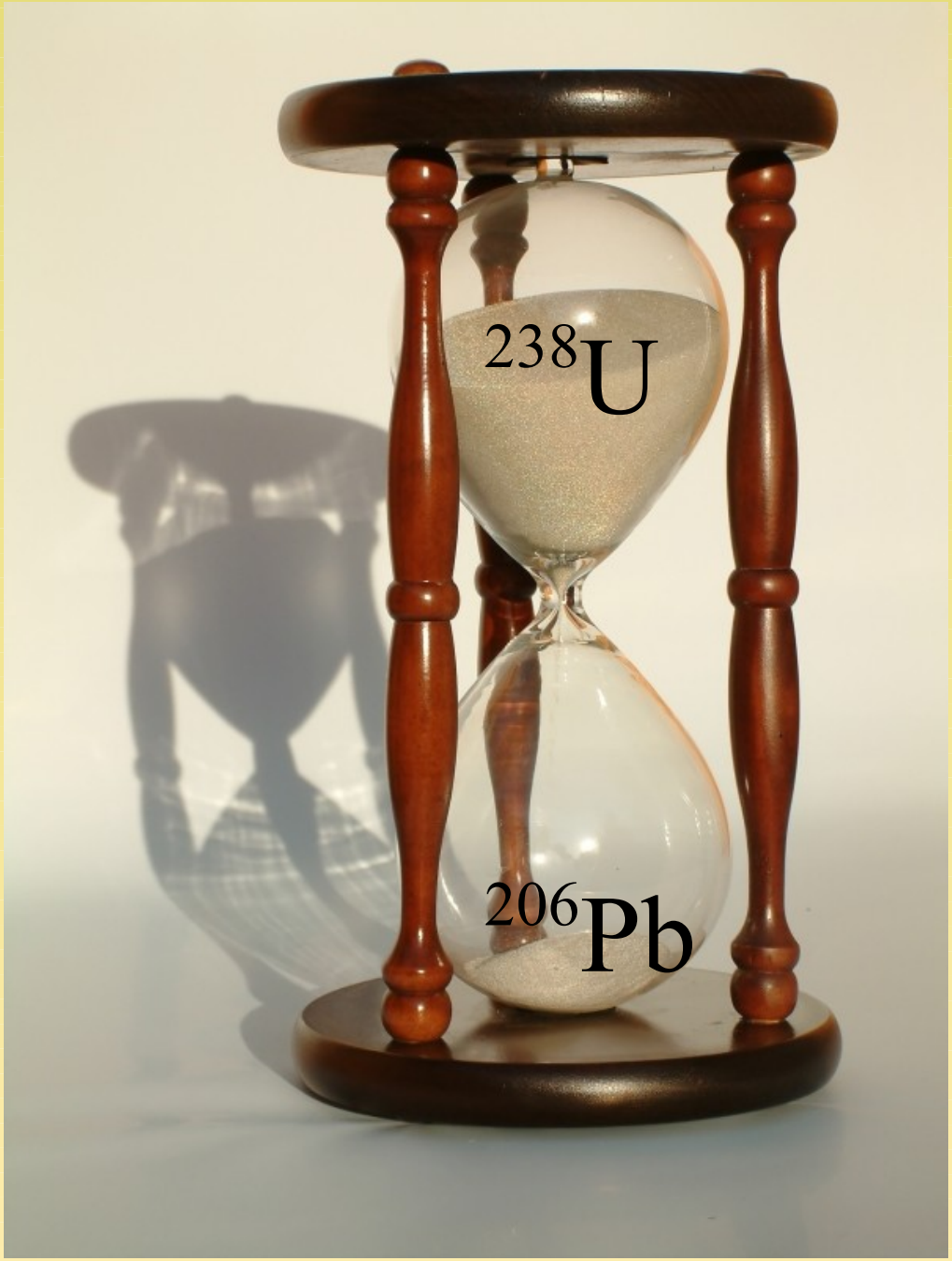
Using multiple isotopes can reduce the uncertainty in the initial amounts

Meteorites

Iron Ores

Moon rocks

All give about 4.5 By



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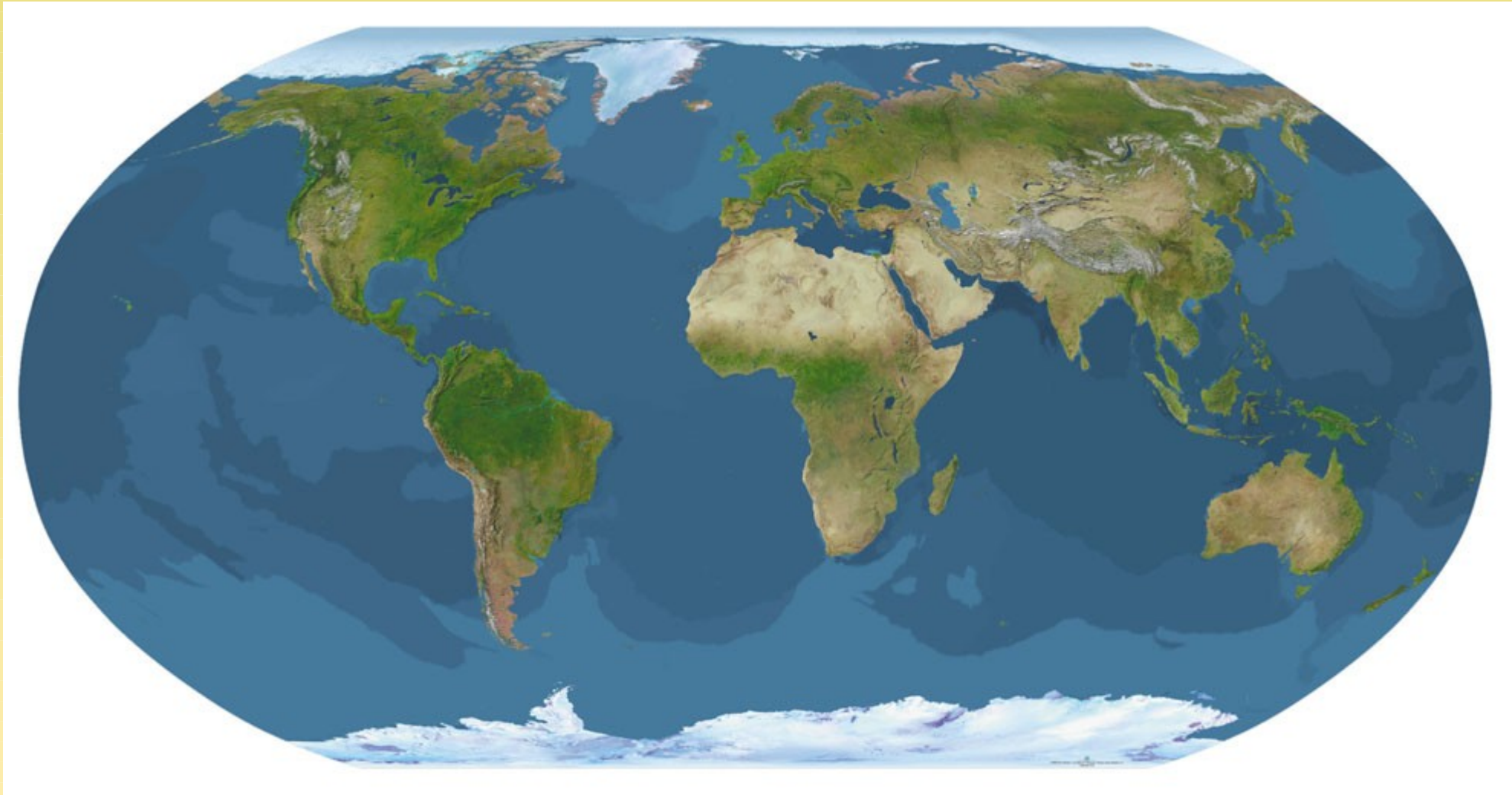
Geologic processes

The continents move



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Geologic processes

The continents matched up by geology

This is how they were arranged about 250 Mya

All the land mass was collected together at least two other times going back over 1By

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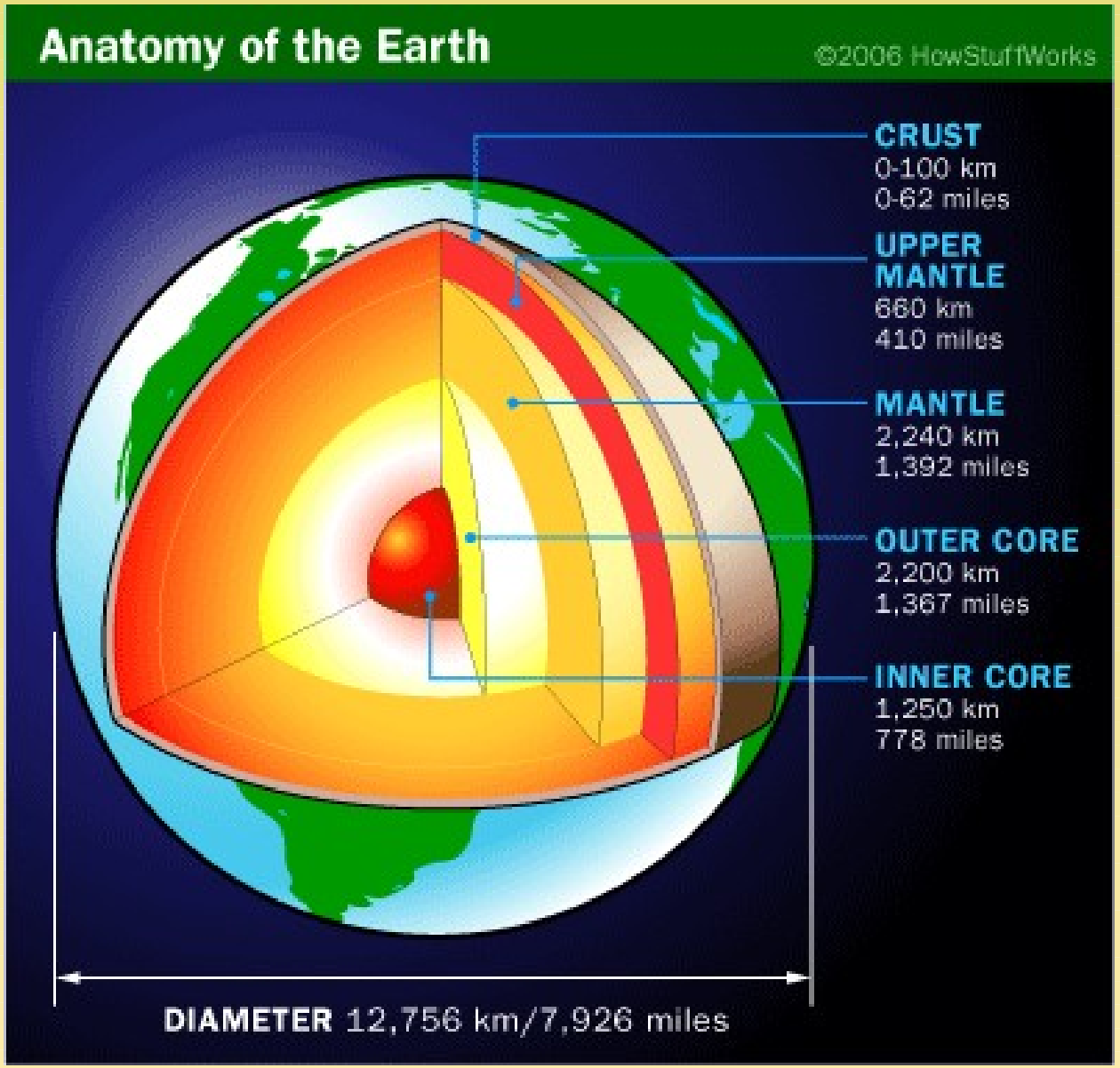
Geologic processes

Calculations of heat flow in the earth gives an age of > 2By

Calculations of the age of the sun from its Hydrogen/Helium ratio gives >4.5By

No physical estimates give a much smaller age of earth



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Irreducible complexity

Critics often say that some organs are “irreducibly complex”

They mean that a less complex organ would serve no purpose, and thus would not provide survival benefits if it were improved

Such an organ would have to be created complete rather than by evolution

Sometimes it is asked, “What good is half an eye?”

Is “irreducible complexity” a useful idea?

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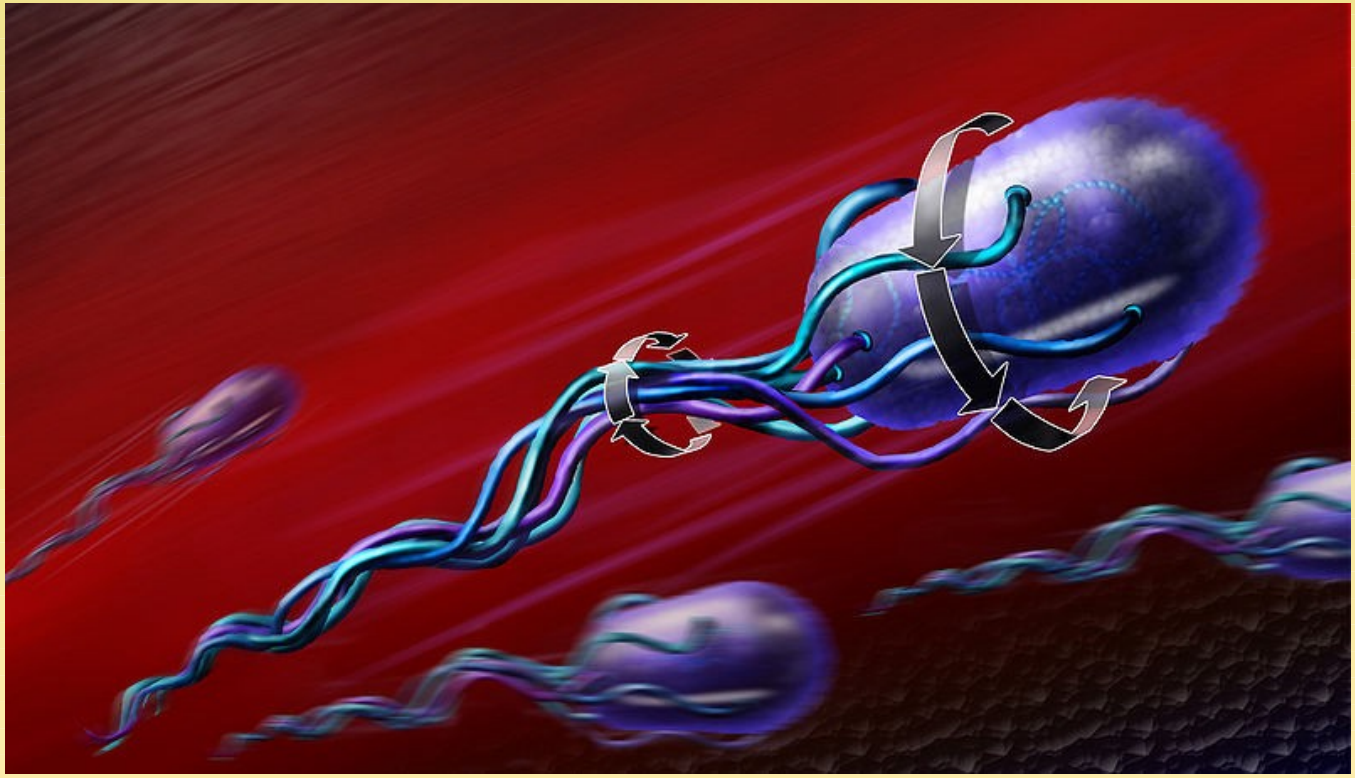
Irreducible complexity

Anatomical structures that perform the same function in different biological species and evolved from the same structure in some ancestor species are ***homologous***

A ***flagellum*** is a tail-like projection that protrudes from the cell body of certain prokaryotic and eukaryotic cells, and functions in locomotion



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Irreducible complexity

Ken Miller is a Professor of Biology at Brown University. He is best known as the plaintiff's lead expert witness in the Kitzmiller v. Dover Area School District trial, challenging the school board's mandate to incorporate intelligent design into the curriculum.

The proponent of irreducible complexity at the trial was Michael Behe.

Bacterial Flagella

Blood Clotting

Evolution

The Genetics of Hominid Primates
(aka, Did Man Come From a Monkey?)

The common ancestry of the great apes (includes humans) is supported by:

- The fossil record
- Abilities and behaviors
- Comparative anatomy

Comparing the genetics of the great apes (hominids) allows us to comment more concretely on whether and how they are related,

After we review some principles of genetics