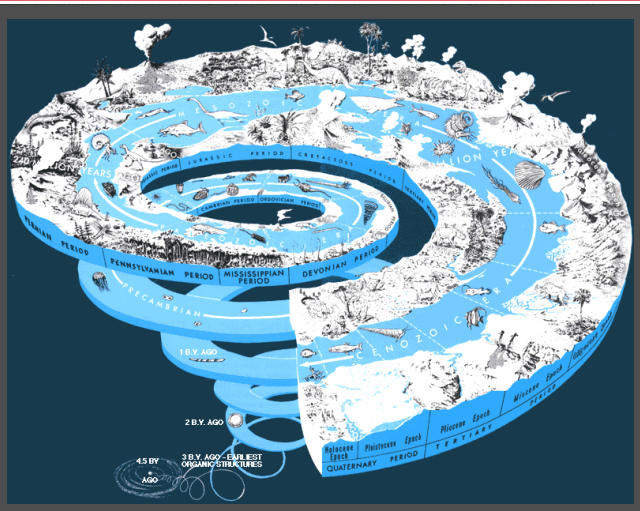
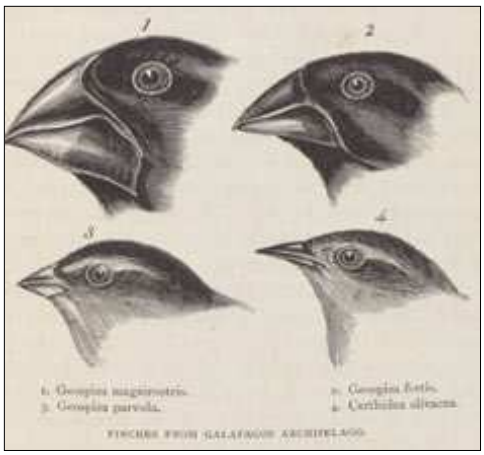
The Ancestor's Tale

An exploration of our ancestors…the past 3.5 billion years



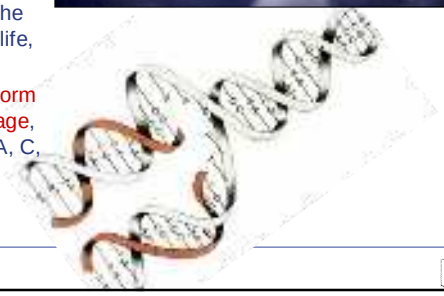
The tenets of evolutionary theory

- More are born than can possibly survive – the Malthusian imperative.
- Random mutations sometimes produce adaptive survival traits – eg a beak that is better able to crack seeds. These are passed on in a higher proportion than nonadaptive characters.
- Adaptation under segregation – eg islands, mountain ridges – produces mutually infertile groups – new species.



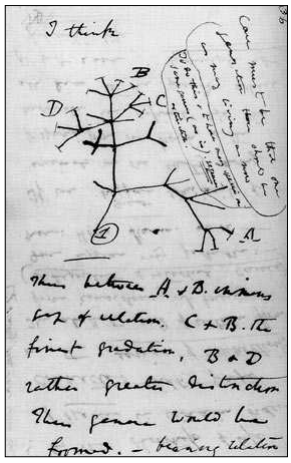
Seeking our nearest common ancestor…

- Every two species has at least one common ancestor.
- We are not descended from the apes; we are just different kinds of apes. We and other primates such as snow monkeys (right) are both descended from another kind of primate. We and chimps, we and birds, each share a single "nearest common ancestor."
- Every form of life, present and past, evolved from common ancestors, all the way back to the first form of bacterial life, 3.5-4 billion years ago.
- This is known because every known form of life shares the same genetic language, DNA, with only 4 "letters" (the bases A, C, G, T), from which is constructed the instruction set (genetic code) for the assembly of our bodies.



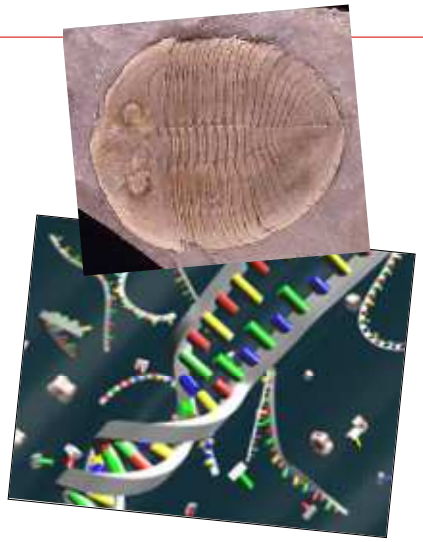
The theme: who were our "most recent common ancestors?"

- Phylogenetic trees, illustrated here by Darwin's original sketch, reveal evolutionary histories: each "fork in the road," or branching point, indicates a common ancestor splitting into two descendants.
- The fewer branching points there are between any two species, the more closely they are related—a feature that has great predictive value. Example: a botanist who discovers a useful pharmacological property in one plant species might investigate "sister" species for similar properties.
- Cladistics is the science of refining this "tree of life" using the tools of paleontology, geology and genetics.



The Tools: Fossils, Rocks and DNA

- Scientists employ shared anatomical features to determine evolutionary relationships. Fossils, along with half-life rock dating, help determine the timing of anatomical changes.
- More recently, they have learned that the history of evolution is also recorded in DNA, the set of instructions for building bodies encoded in all living cells. When plants and animals reproduce, they pass copies of their DNA on to their offspring.
- Over time, the DNA of a species changes, usually as a result of copying errors (mutations). Scientists can compare DNA to help discover evolutionary linkages: in general, the greater the difference in DNA between two species, the more time must have passed since the two groups were one, since they diverged from a common ancestor.



You old fossil

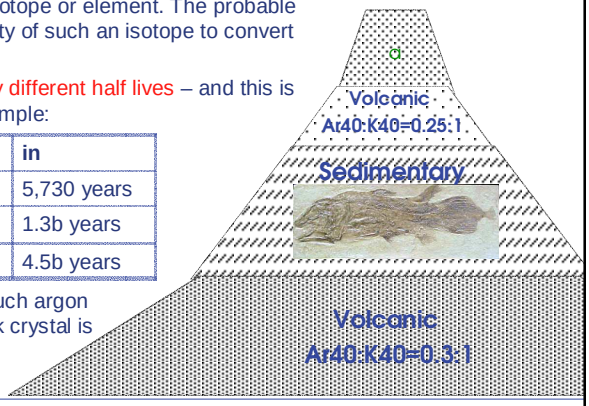
- Fossils – shapes imprinted in rocks – tell stories of ancient organisms' structures. Taken in the context of rocks and chemicals, we can learn their ecology and adaptations.
- The earliest bacterial fossils date back to 3.5 billion years ago.
- The famous fossil at right is *Archaeopteryx*, whose discovery helped us to learn that birds are descended from the dinosaurs.

Dating a rock star

- Successive layers have long been distinguished by their fossils, but today's geologists use half-life dating.
- Many elements, such as carbon and hydrogen, have radioactive (decaying) variants called isotopes. The decay converts them into another isotope or element. The probable time for half of a given quantity of such an isotope to convert is its half life.
- Different isotopes have vastly different half lives – and this is what enables dating, For example:

Half of	Decays to	in
Carbon 14	Nitrogen 14	5,730 years
Potassium 40	Argon 40	1.3b years
Uranium 236	Lead 206	4.5b years

- Example: if there is 2x as much argon 40 as potassium 40, the rock crystal is 2.6 billion years old.
- How old is the coelacanth?



Answer: between 325 and 390 mya

The Double Helix

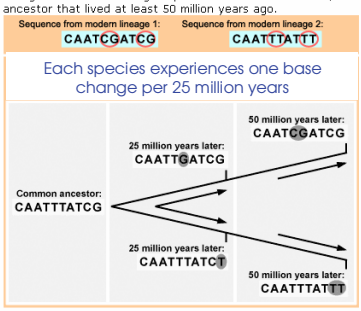
- The history of our evolution is recorded in each person's DNA. Our unique human DNA "instruction set" is like a computer program employing a limited set of subroutines in a programming language common to all known forms of life.
- The 4 "letters" spell 64 "words" (codons). A "sentence" of codons specifying a particular protein molecule is called a gene.
- Each human cell contains about 30,000 genes. Most strings of our DNA are meaningless or unused, like early drafts of a program on a cluttered hard disk.
- These useful subroutines and early versions, which we have in common with most other living organisms, record the story of our kinship and evolution.
- The DNA instruction set has been passed on, with minor random changes, from generation to generation, for almost four billion years.

"Everything about a plant or animal, including its bodily form, its inherited behavior, and the chemistry of its cells, is a coded message about the worlds in which its ancestors survived; the food they sought; the predators they escaped; the climates they endured; the mates they beguiled. The message is ultimately scripted in the DNA that fell through the succession of sieves that is natural selection." (Dawkins)

Details

For the past 40 years, evolutionary biologists have been investigating the possibility that some evolutionary changes occur in a clock-like fashion. Over the course of millions of years, mutations may build up in any given stretch of DNA at a reliable rate. For example,the gene that codes for the protein alpha-globin (a component of hemoglobin) experiences base changes at a rate of .56 changes per base pair per billion years*. If this rate is reliable, the gene could be used as a molecular clock.

When a stretch of DNA does indeed behave like a molecular clock, it becomes a powerful tool for estimating the dates of lineage-splitting events. For example, imagine that a length of DNA found in two species differs by four bases (as shown below) and we know that this entire length of DNA changes at a rate of approximately one base per 25 million years. That means that the two DNA versions differ by 100 million years of evolution and that their common ancestor lived 50 million years ago. Since each lineage experienced its own evolution, the two species must have descended from a common ancestor that lived at least 50 million years ago.

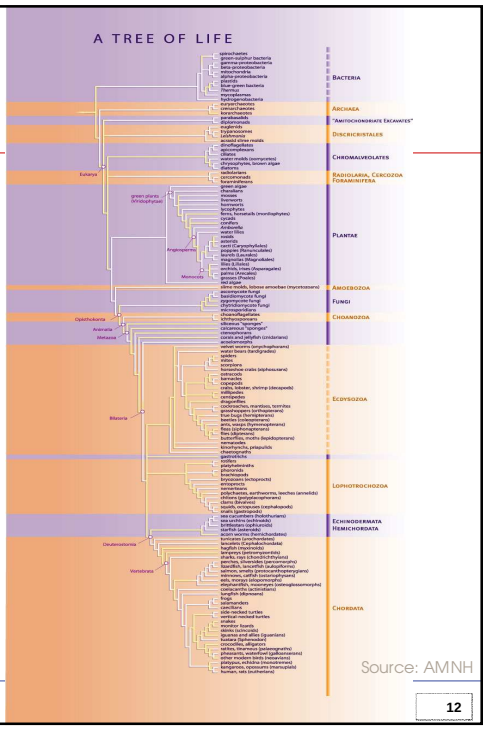


This general technique has been used to investigate several important issues, including the origin of modern humans, the date of the human/chimpanzee divergence, and the date of the Cambrian "explosion."

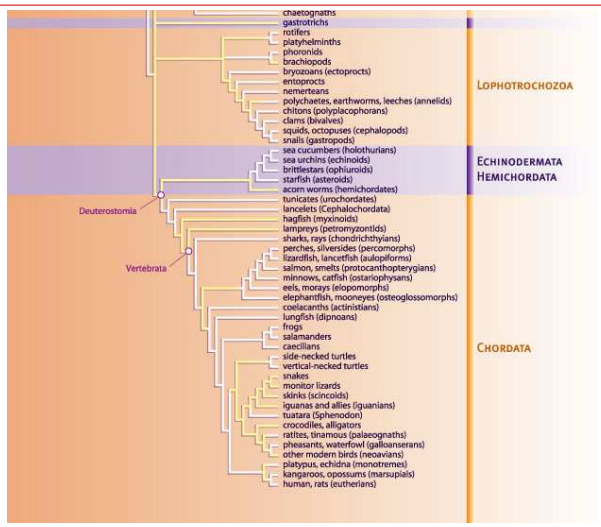
http://evolution.berkeley.edu/evolibrary/article/side_0_0/molecclocks_01

From DNA to a phylogram

- Organisms' "characters" including DNA similarities help form groupings – but which groupings to avert superfluous matches?
- The goal is to describe evolutionary paths.
- Among other methods, Bayesian maximum likelihood analysis seem to work well.
- Much debate prevails – especially as to how to organize the early groups.

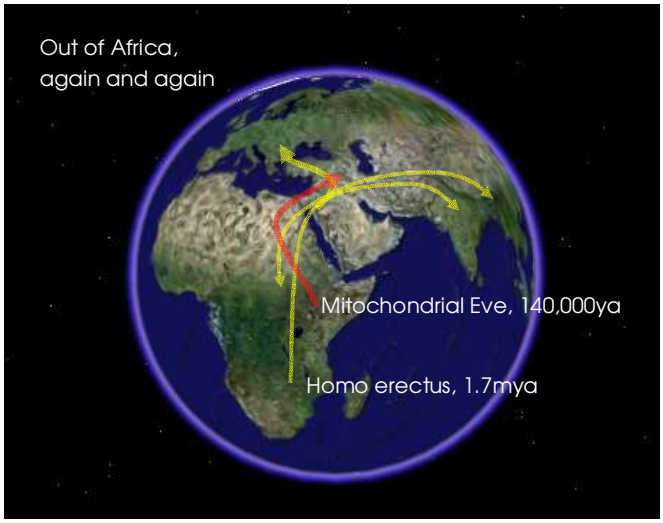


Of Rats and Men



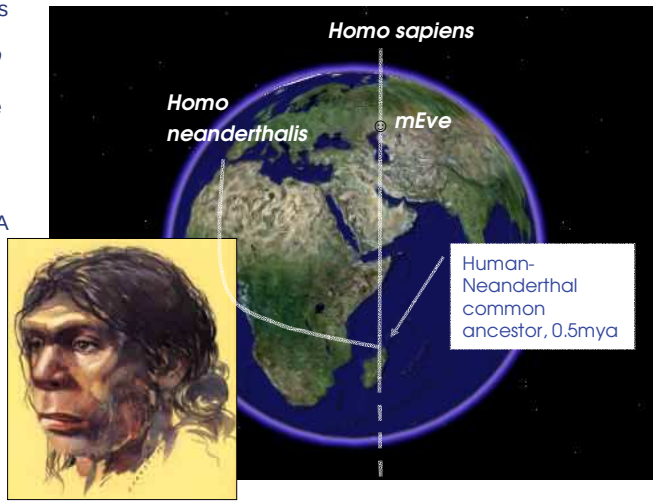
Let's start our journey, and meet the first humans

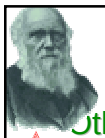
- Mitochondrial DNA is a section of DNA so tightly bound that it travels through history as a single unit
- mDNA, carried exclusively through the female line, lets us trace the most recent female ancestor of all living humans.
- Other DNA groups, too, help tell the Ancestor's Tale



We meet people we'll never meet

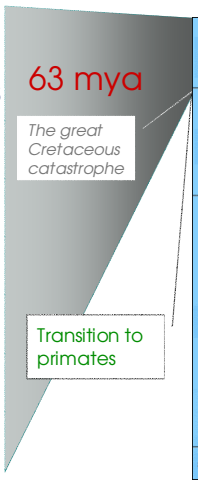
- Neanderthal man is closely related to our species, *Homo sapiens.*
- But fossil evidence finds no trace of any of their descendents, and newly discovered Neanderthal mDNA strings are quite distinct from those of all surviving humans.



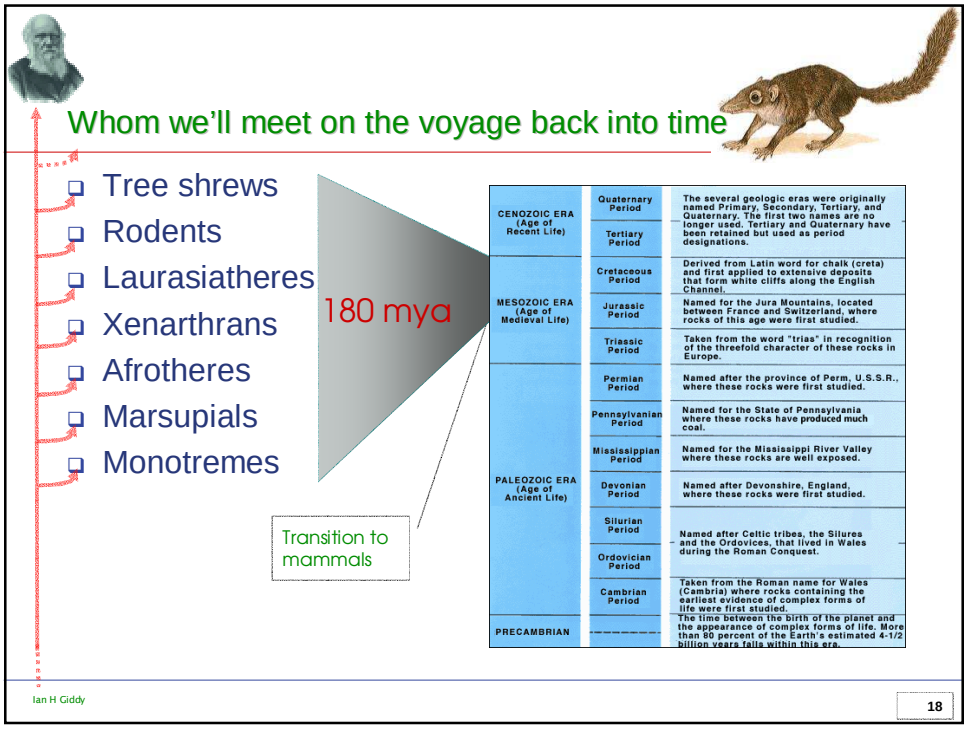


Others whom we'll meet on the voyage back into time

- African ape-men
- Chimpanzees
- Gorillas
- Orang utans
- Gibbons
- Old world monkeys
- New world monkeys
- Tarsiers
- Lemurs



CENOZOIC ERA (Age of Recent Life)	Quaternary Period	The several geologic eras were originally named Primary, Secondary, Tertiary, and Quaternary. The first two names are no longer used. Tertiary and Quaternary have been retained but used as period designations.
	Tertiary Period	
MESOZOIC ERA (Age of Medieval Life)	Cretaceous Period	Derived from Latin word for chalk (creta) and first applied to extensive deposits that form white cliffs along the English Channel.
	Jurassic Period	Named for the Jura Mountains, located between France and Switzerland, where rocks of this age were first studied.
	Triassic Period	Taken from the word "trias" in recognition of the threefold character of these rocks in Europe.
PALEOZOIC ERA (Age of Ancient Life)	Permian Period	Named after the province of Perm, U.S.S.R., where these rocks were first studied.
	Pennsylvanian Period	Named for the State of Pennsylvania where these rocks have produced much coal.
	Mississippian Period	Named for the Mississippi River Valley where these rocks are well exposed.
	Devonian Period	Named after Devonshire, England, where these rocks were first studied.
	Silurian Period	Named after Celtic tribes, the Silures and the Ordovices, that lived in Wales during the Roman Conquest.
	Ordovician Period	
	Cambrian Period	Taken from the Roman name for Wales (Cambria) where rocks containing the earliest evidence of complex forms of life were first studied.
PRECAMBRIAN	----------	The time between the birth of the planet and the appearance of complex forms of life. More than 80 percent of the Earth's estimated 4-1/2 billion years falls within this era.


Whom we'll meet on the voyage back into time
Tree shrews
Rodents
Laurasiatheres
Xenarthrans
Afrotheres
Marsupials
Monotremes
180 mya
Transition to mammals
CENOZOIC ERA (Age of Recent Life)
Quaternary Period
Tertiary Period
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Ian H Giddy
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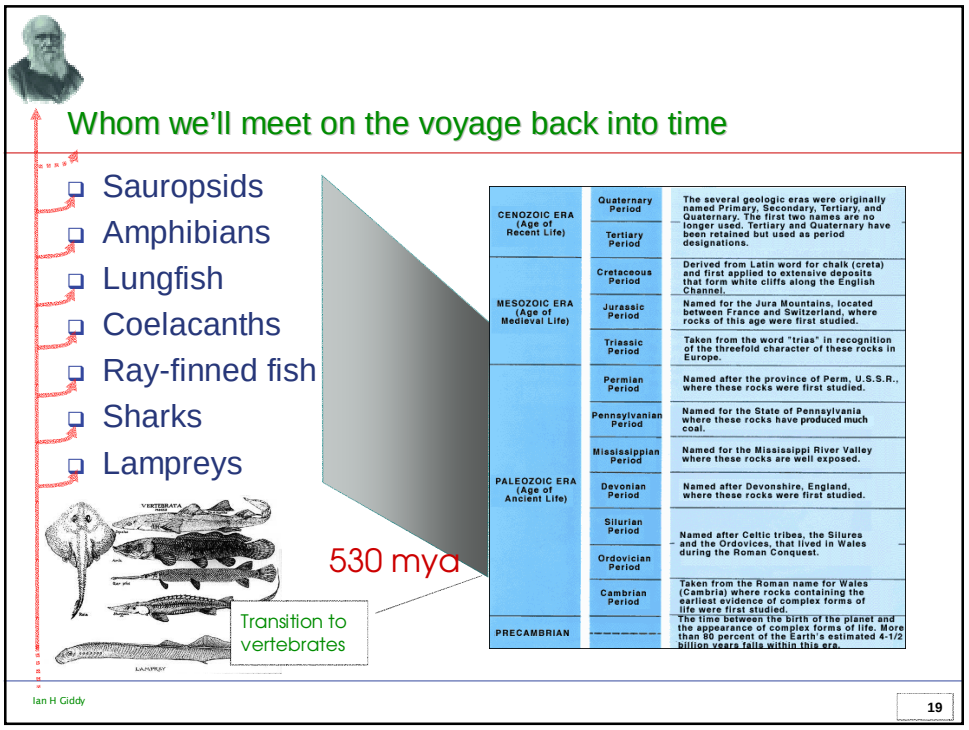
Whom we'll meet on the voyage back into time
Sauropsids
Amphibians
Lungfish
Coelacanths
Ray-finned fish
Sharks
Lampreys
530 mya
Transition to vertebrates
CENOZOIC ERA (Age of Recent Life)
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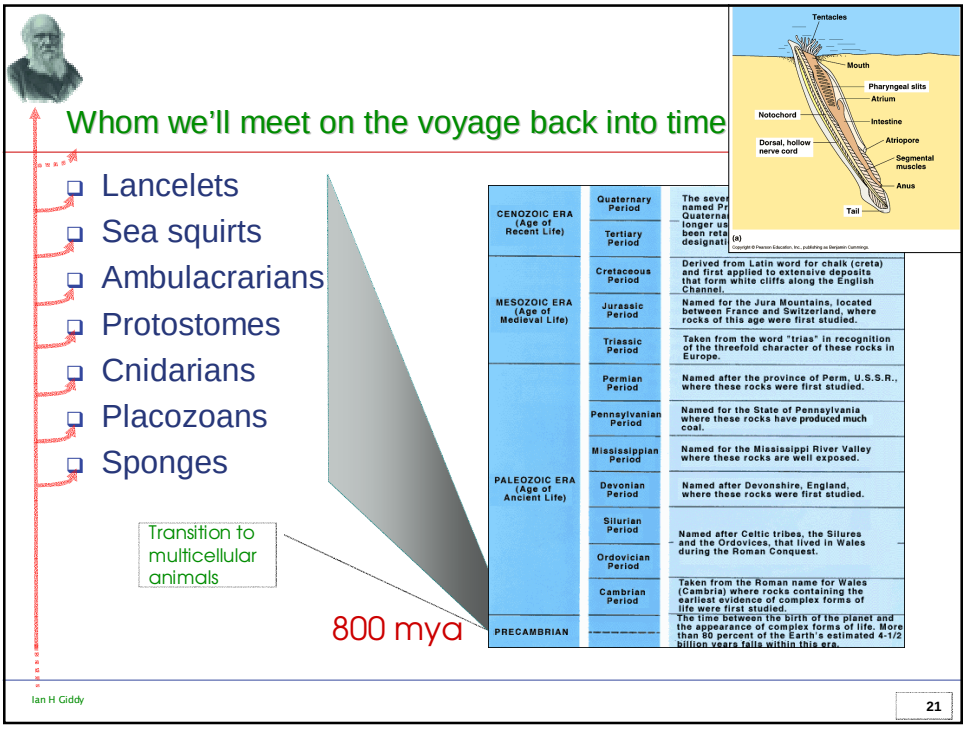
Whom we'll meet on the voyage back into time
Lancelets
Sea squirts
Ambulacrarians
Protostomes
Cnidarians
Placozoans
Sponges
Transition to multicellular animals
800 mya
Tentacles
Mouth
Pharyngeal slits
Atrium
Notochord
Intestine
Dorsal, hollow nerve cord
Atriopore
Segmental muscles
Anus
Tail
(a)
CENOZOIC ERA (Age of Recent Life)
Quaternary Period
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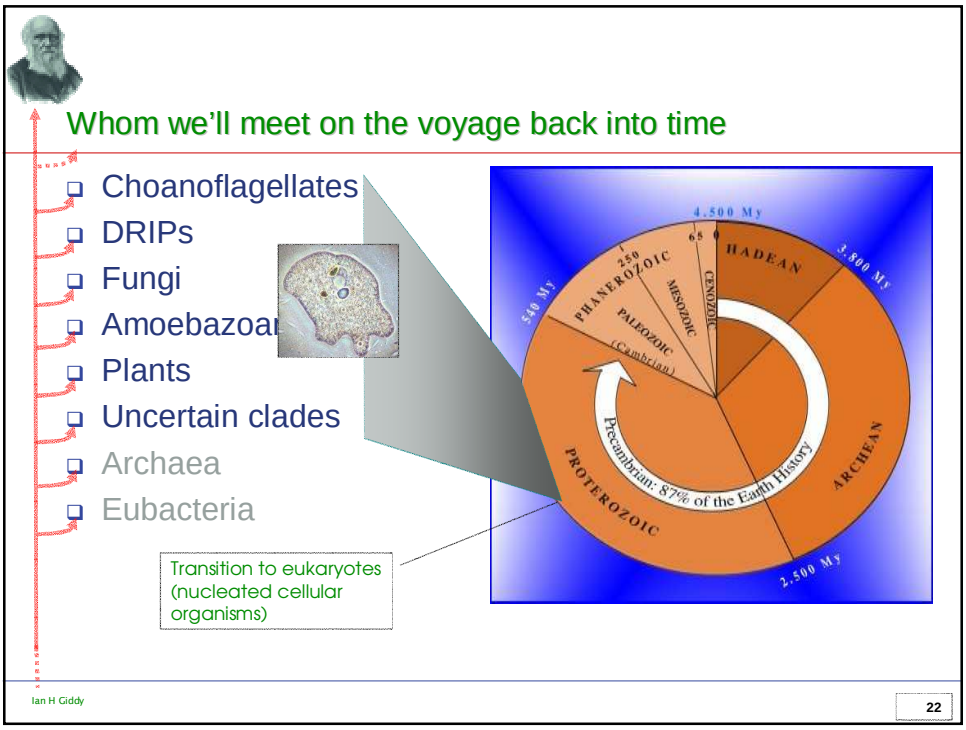
Whom we'll meet on the voyage back into time
Choanoflagellates
DRIPs
Fungi
Amoebazoa
Plants
Uncertain clades
Archaea
Eubacteria
Transition to eukaryotes (nucleated cellular organisms)
4,500 My
65
250
540 My
3,800 My
2,500 My
HADEAN
ARCHEAN
PROTEROZOIC
PHANEROZOIC
PALEOZOIC
(Cambrian)
MESOZOIC
CENOZOIC
Precambrian: 87% of the Earth History
Ian H Giddy
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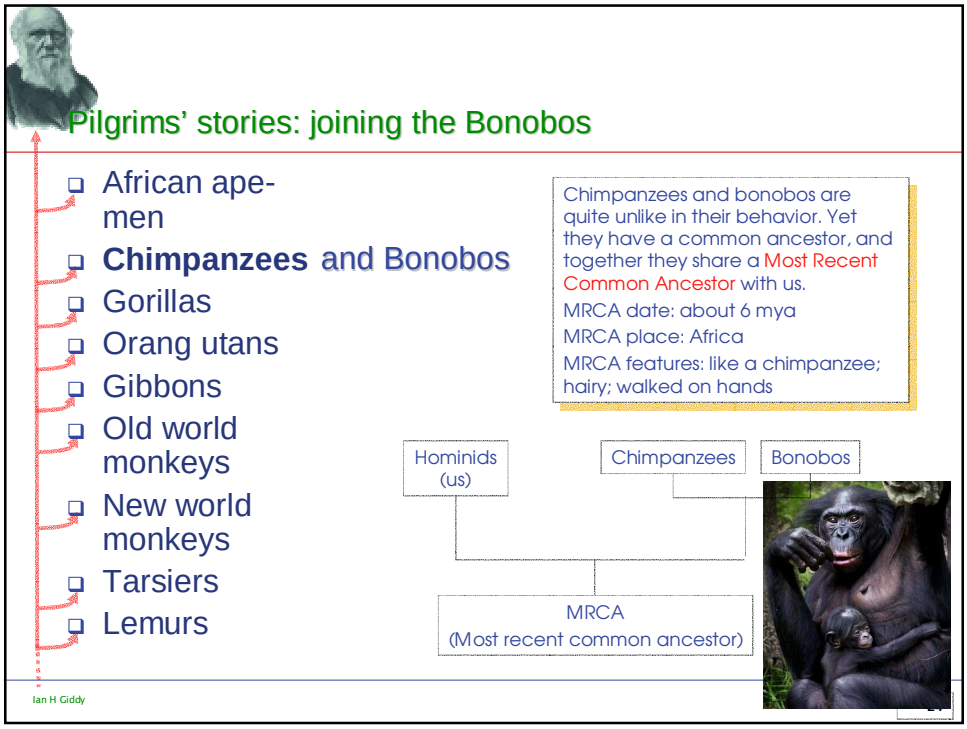
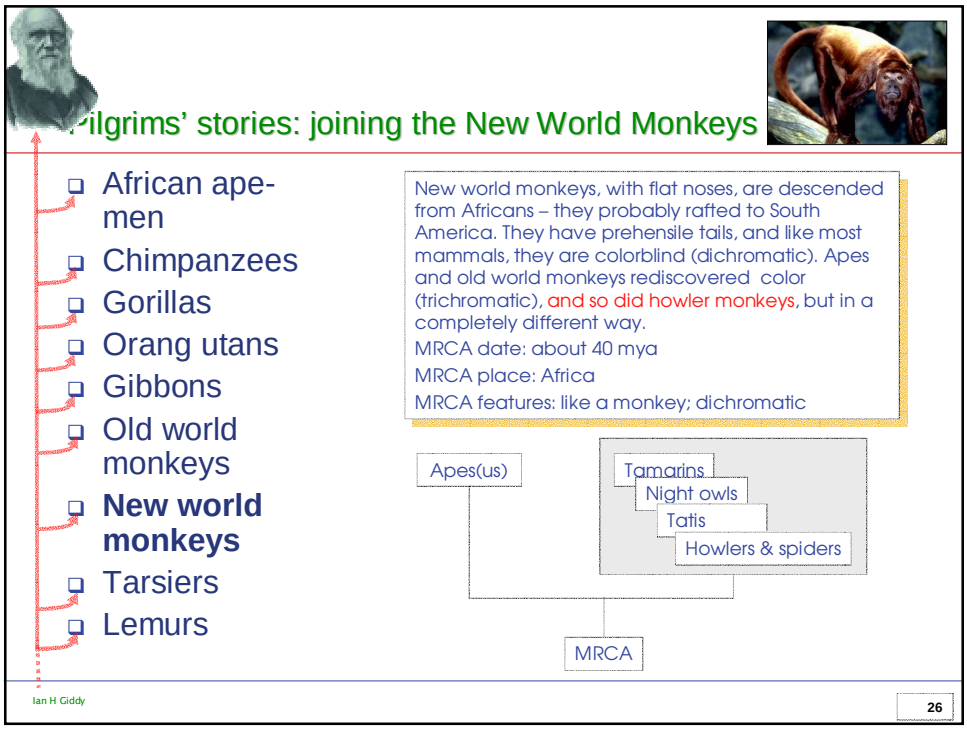

Pilgrims' stories: joining the Bonobos
African ape-men
Chimpanzees and Bonobos
Gorillas
Orang utans
Gibbons
Old world monkeys
New world monkeys
Tarsiers
Lemurs
Chimpanzees and bonobos are quite unlike in their behavior. Yet they have a common ancestor, and together they share a Most Recent Common Ancestor with us.
MRCA date: about 6 mya
MRCA place: Africa
MRCA features: like a chimpanzee; hairy; walked on hands
Hominids (us)
Chimpanzees
Bonobos
MRCA
(Most recent common ancestor)
Ian H Giddy


Pilgrims' stories: joining the New World Monkeys
African ape-men
Chimpanzees
Gorillas
Orang utans
Gibbons
Old world monkeys
New world monkeys
Tarsiers
Lemurs
New world monkeys, with flat noses, are descended from Africans – they probably rafted to South America. They have prehensile tails, and like most mammals, they are colorblind (dichromatic). Apes and old world monkeys rediscovered color (trichromatic), and so did howler monkeys, but in a completely different way.
MRCA date: about 40 mya
MRCA place: Africa
MRCA features: like a monkey; dichromatic
Apes(us)
Tamarins
Night owls
Tatis
Howlers & spiders
MRCA
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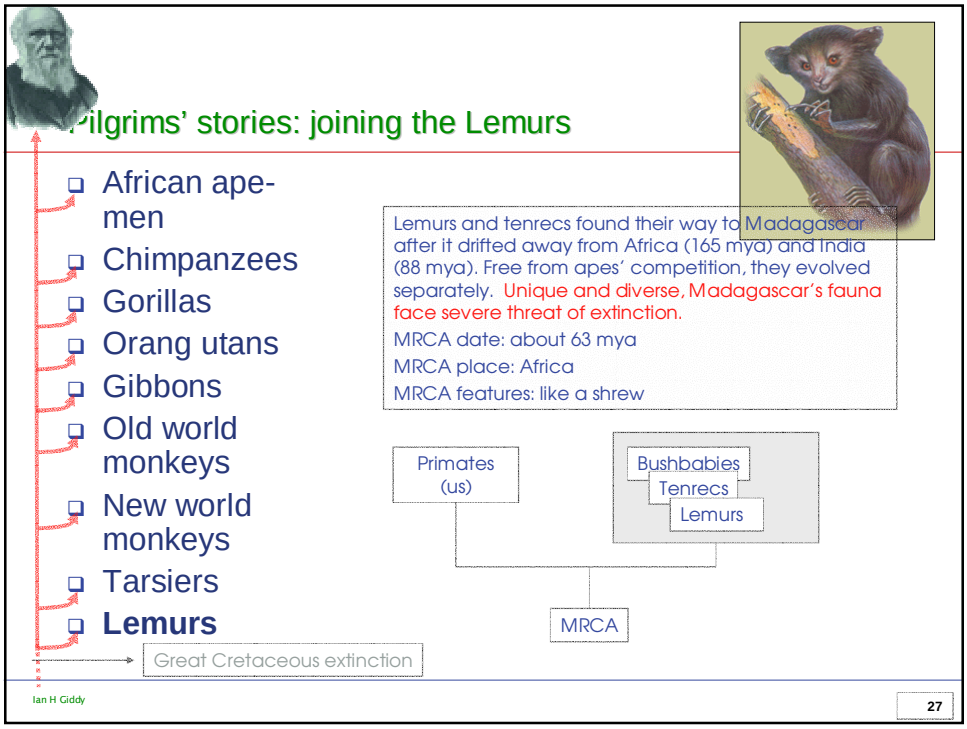
Pilgrims' stories: joining the Lemurs
African ape-men
Chimpanzees
Gorillas
Orang utans
Gibbons
Old world monkeys
New world monkeys
Tarsiers
Lemurs
Great Cretaceous extinction
Lemurs and tenrecs found their way to Madagascar after it drifted away from Africa (165 mya) and India (88 mya). Free from apes' competition, they evolved separately. Unique and diverse, Madagascar's fauna face severe threat of extinction.
MRCA date: about 63 mya
MRCA place: Africa
MRCA features: like a shrew
Primates (us)
Bushbabies
Tenrecs
Lemurs
MRCA
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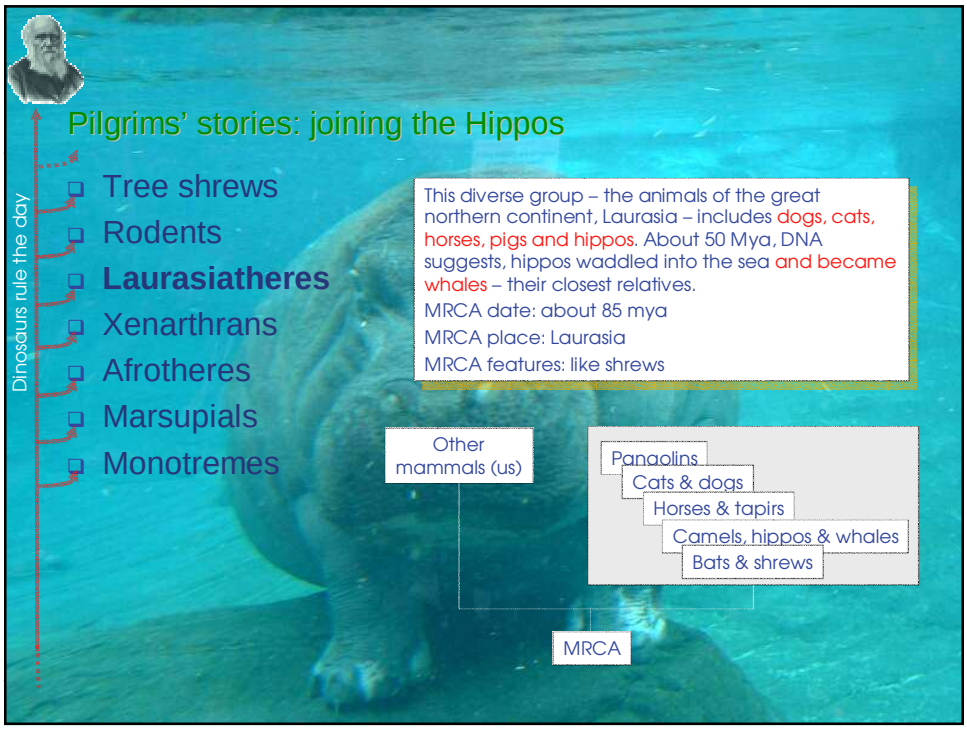
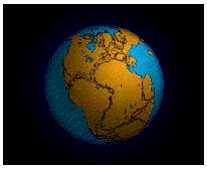

Pilgrims' stories: joining the Hippos
Dinosaurs rule the day
Tree shrews
Rodents
Laurasiatheres
Xenarthrans
Afrotheres
Marsupials
Monotremes
This diverse group – the animals of the great northern continent, Laurasia – includes dogs, cats, horses, pigs and hippos. About 50 Mya, DNA suggests, hippos waddled into the sea and became whales – their closest relatives.
MRCA date: about 85 mya
MRCA place: Laurasia
MRCA features: like shrews
Other mammals (us)
Pangolins
Cats & dogs
Horses & tapirs
Camels, hippos & whales
Bats & shrews
MRCA

Laurasia and Gondwana

- About 200 million years ago, the supercontinent Pangaea started to split into Laurasia and Gondwana.
- Gondwana began to break up in the late Jurassic (about 160 mya) when Africa became separated and began to drift slowly northwards.

TRIASSIC
200 million years ago



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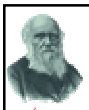
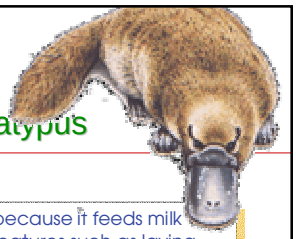


Pilgrims' stories: joining the Duck-Billed Platypus



Dinosaurs rule the day

- Tree shrews
- Rodents
- Laurasiatheres
- Xenarthrans
- Afrotheres
- Marsupials
- **Monotremes**

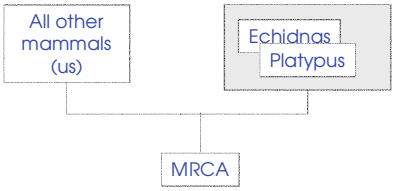
Transition to mammals

The platypus is a mammal because it feeds milk its young, but it has reptile features such as laying eggs. Its most amazing quality lies in its bill: it searches muddy pools for prey with its eyes, ears and nose closed, using only its bill to detect electrical fields of nearby invertebrates.

MRCA date: about 180 mya

MRCA place: Pangaea

MRCA features: like a rodent



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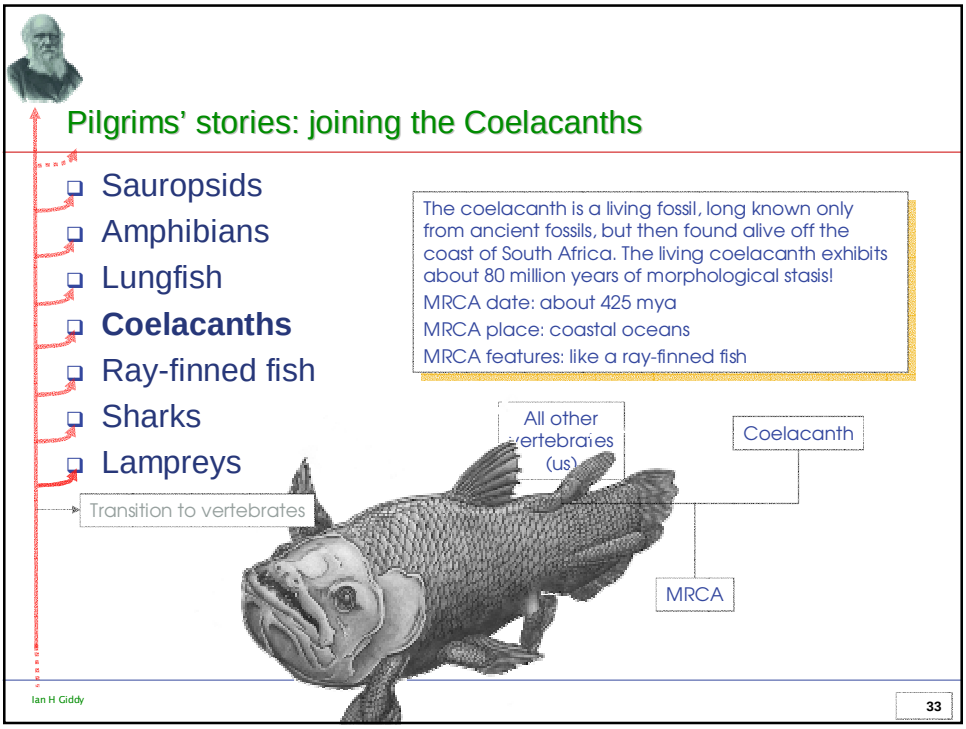
Pilgrims' stories: joining the Coelacanths
Sauropsids
Amphibians
Lungfish
Coelacanths
Ray-finned fish
Sharks
Lampreys
Transition to vertebrates
The coelacanth is a living fossil, long known only from ancient fossils, but then found alive off the coast of South Africa. The living coelacanth exhibits about 80 million years of morphological stasis!
MRCA date: about 425 mya
MRCA place: coastal oceans
MRCA features: like a ray-finned fish
All other vertebrates (us)
Coelacanth
MRCA
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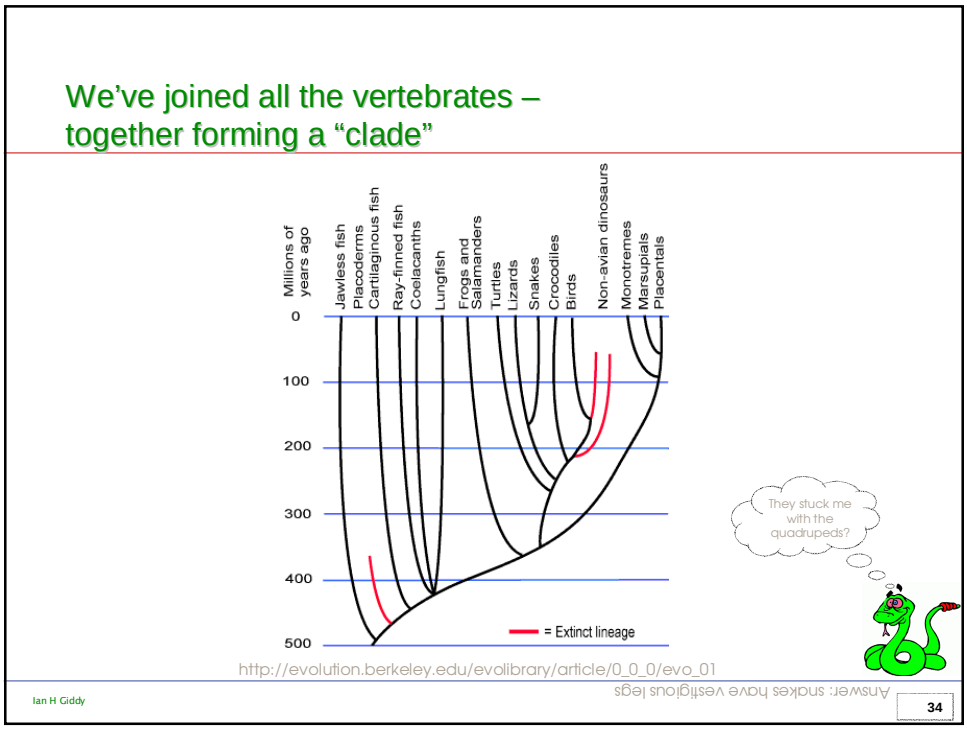
We've joined all the vertebrates – together forming a "clade"
Millions of years ago
Jawless fish
Placoderms
Cartilaginous fish
Ray-finned fish
Coelacanths
Lungfish
Frogs and Salamanders
Turtles
Lizards
Snakes
Crocodiles
Birds
Non-avian dinosaurs
Monotremes
Marsupials
Placentals
0
100
200
300
400
500
= Extinct lineage
They stuck me with the quadrupeds?
http://evolution.berkeley.edu/evolibrary/article/0_0_0/evo_01
Answer: snakes have vestigious legs
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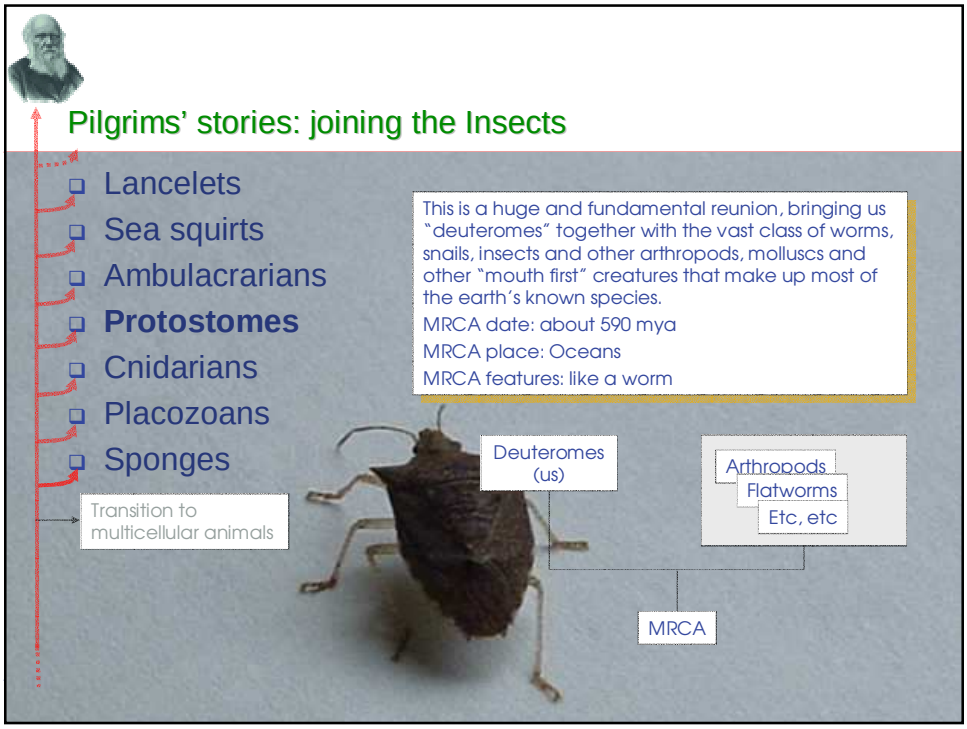
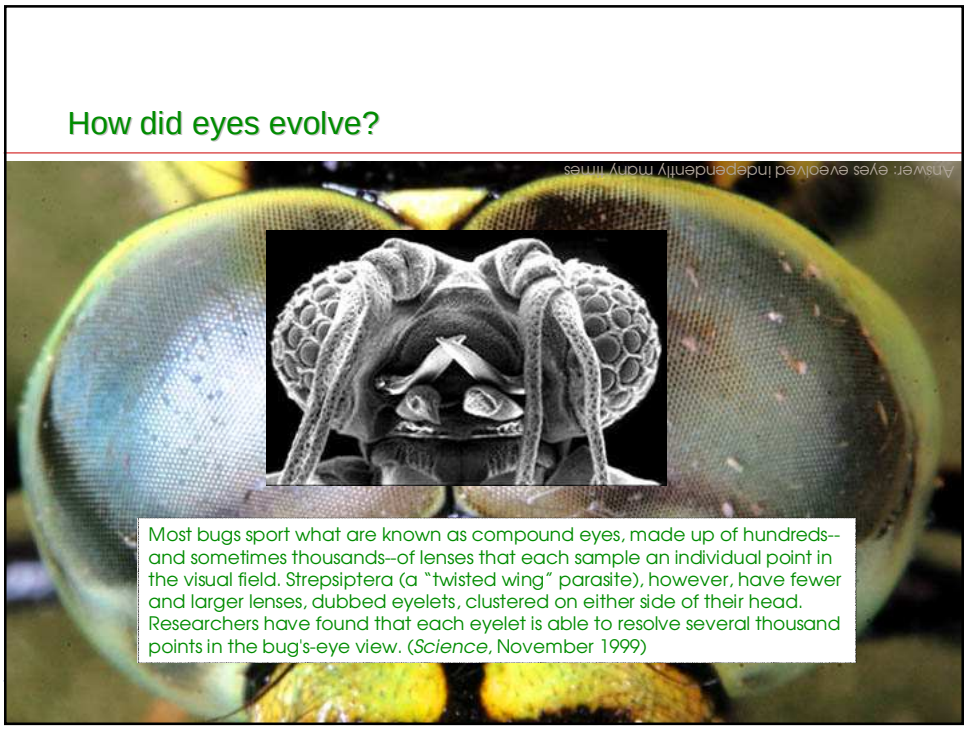
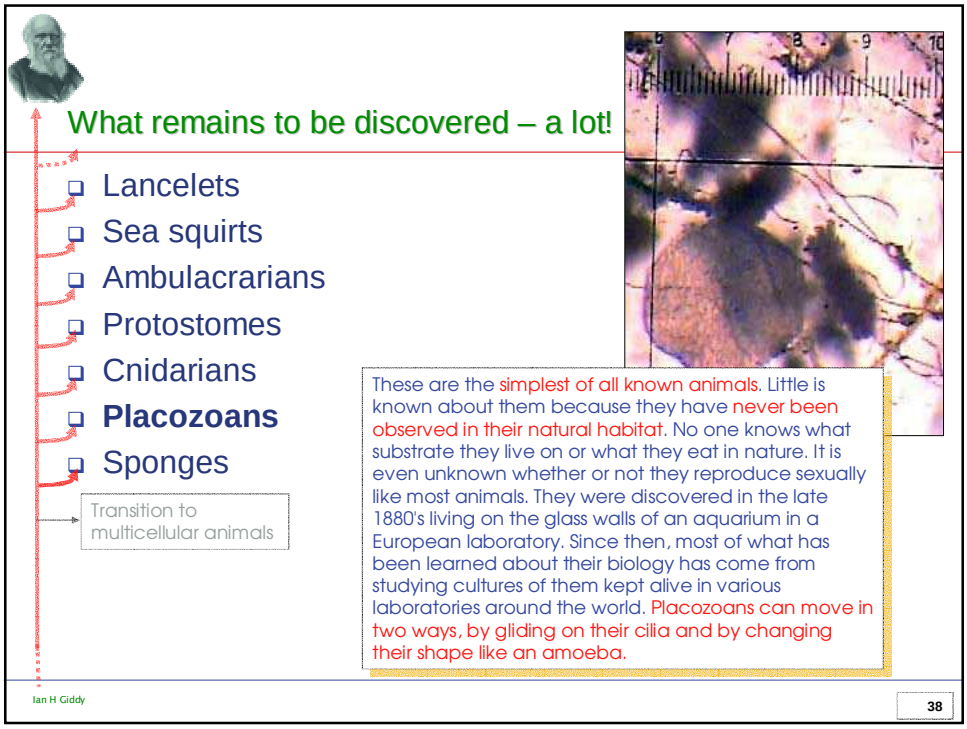

Pilgrims' stories: joining the Insects
Lancelets
Sea squirts
Ambulacrarians
Protostomes
Cnidarians
Placozoans
Sponges
Transition to multicellular animals
This is a huge and fundamental reunion, bringing us "deuteromes" together with the vast class of worms, snails, insects and other arthropods, molluscs and other "mouth first" creatures that make up most of the earth's known species.
MRCA date: about 590 mya
MRCA place: Oceans
MRCA features: like a worm
Deuteromes (us)
Arthropods
Flatworms
Etc, etc
MRCA


How did eyes evolve?
Answer: eyes evolved independently many times
Most bugs sport what are known as compound eyes, made up of hundreds--and sometimes thousands--of lenses that each sample an individual point in the visual field. Strepsiptera (a "twisted wing" parasite), however, have fewer and larger lenses, dubbed eyelets, clustered on either side of their head. Researchers have found that each eyelet is able to resolve several thousand points in the bug's-eye view. (*Science*, November 1999)


What remains to be discovered – a lot!
Lancelets
Sea squirts
Ambulacrarians
Protostomes
Cnidarians
Placozoans
Sponges
Transition to multicellular animals
These are the simplest of all known animals. Little is known about them because they have never been observed in their natural habitat. No one knows what substrate they live on or what they eat in nature. It is even unknown whether or not they reproduce sexually like most animals. They were discovered in the late 1880's living on the glass walls of an aquarium in a European laboratory. Since then, most of what has been learned about their biology has come from studying cultures of them kept alive in various laboratories around the world. Placozoans can move in two ways, by gliding on their cilia and by changing their shape like an amoeba.
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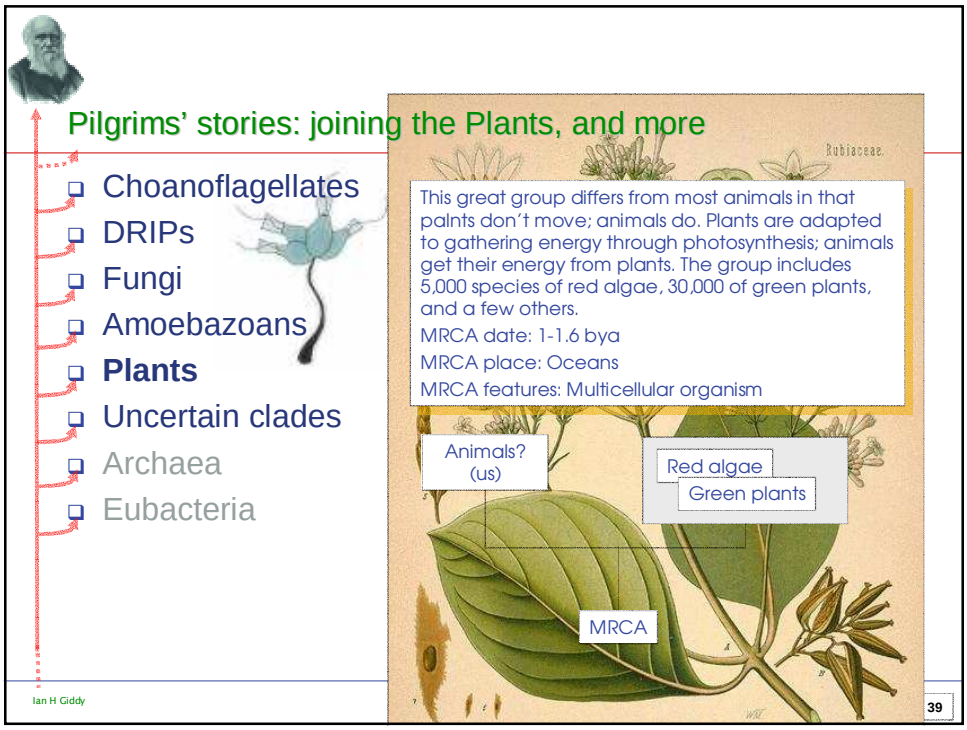
Pilgrims' stories: joining the Plants, and more
Choanoflagellates
DRIPs
Fungi
Amoebazoans
Plants
Uncertain clades
Archaea
Eubacteria
This great group differs from most animals in that palnts don't move; animals do. Plants are adapted to gathering energy through photosynthesis; animals get their energy from plants. The group includes 5,000 species of red algae, 30,000 of green plants, and a few others.
MRCA date: 1-1.6 bya
MRCA place: Oceans
MRCA features: Multicellular organism
Animals? (us)
Red algae
Green plants
MRCA
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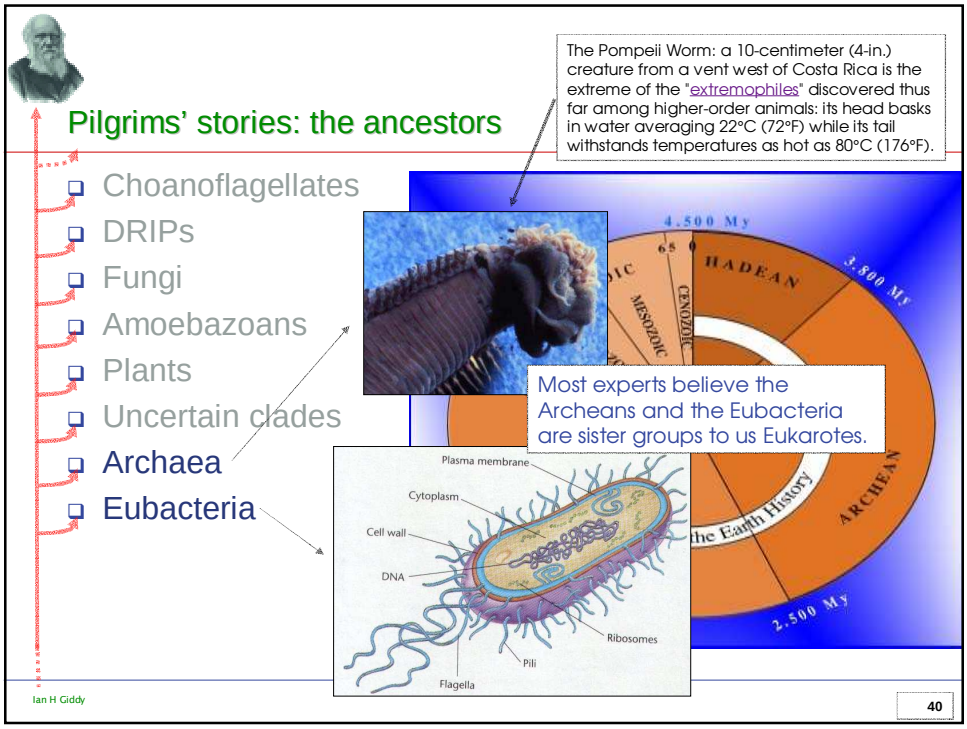
Pilgrims' stories: the ancestors
Choanoflagellates
DRIPs
Fungi
Amoebazoans
Plants
Uncertain clades
Archaea
Eubacteria
The Pompeii Worm: a 10-centimeter (4-in.) creature from a vent west of Costa Rica is the extreme of the "extremophiles" discovered thus far among higher-order animals: its head basks in water averaging 22°C (72°F) while its tail withstands temperatures as hot as 80°C (176°F).
Most experts believe the Archeans and the Eubacteria are sister groups to us Eukarotes.
4,500 My
HADEAN
3,800 My
MESOZOIC
CENOZOIC
ARCHEAN
2,500 My
the Earth History
Plasma membrane
Cytoplasm
Cell wall
DNA
Ribosomes
Pili
Flagella
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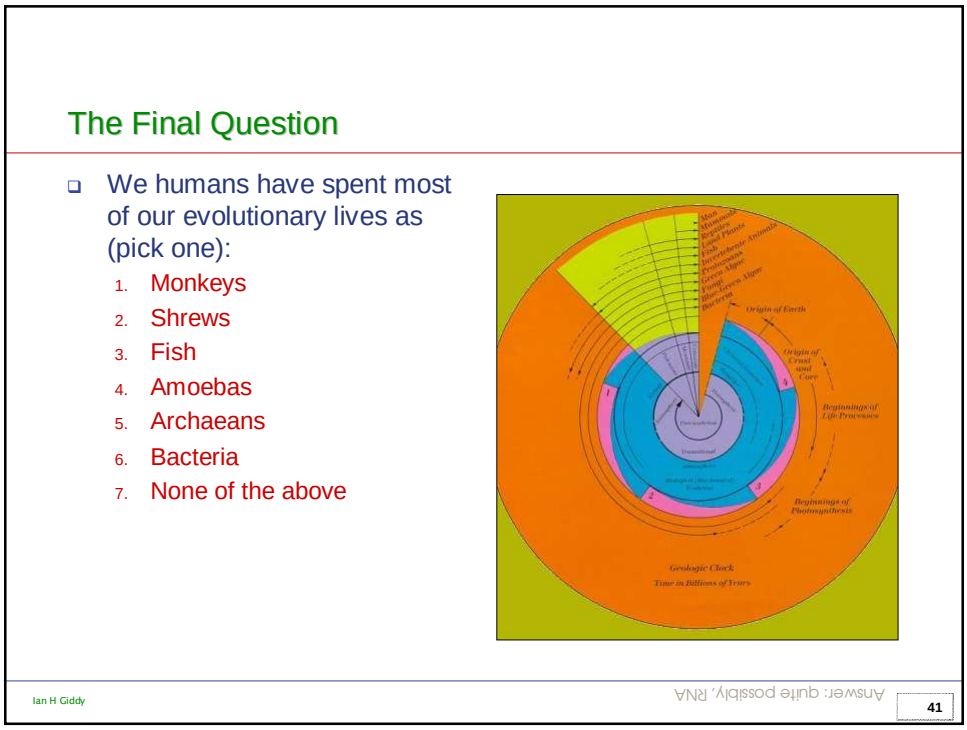
The Final Question
We humans have spent most of our evolutionary lives as (pick one):
1. Monkeys
2. Shrews
3. Fish
4. Amoebas
5. Archaeans
6. Bacteria
7. None of the above
Origin of Earth
Origin of Crust and Core
Beginnings of Life Processes
Beginnings of Photosynthesis
Geologic Clock
Time in Billions of Years
Ian H Giddy
Answer: quite possibly, RNA
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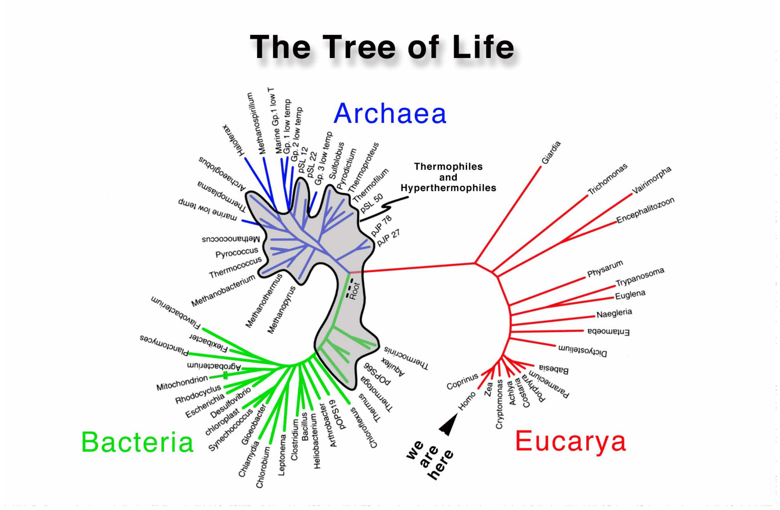
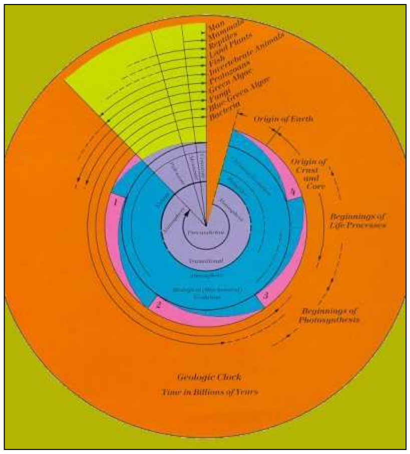
Quite possibly, “None of the above.”

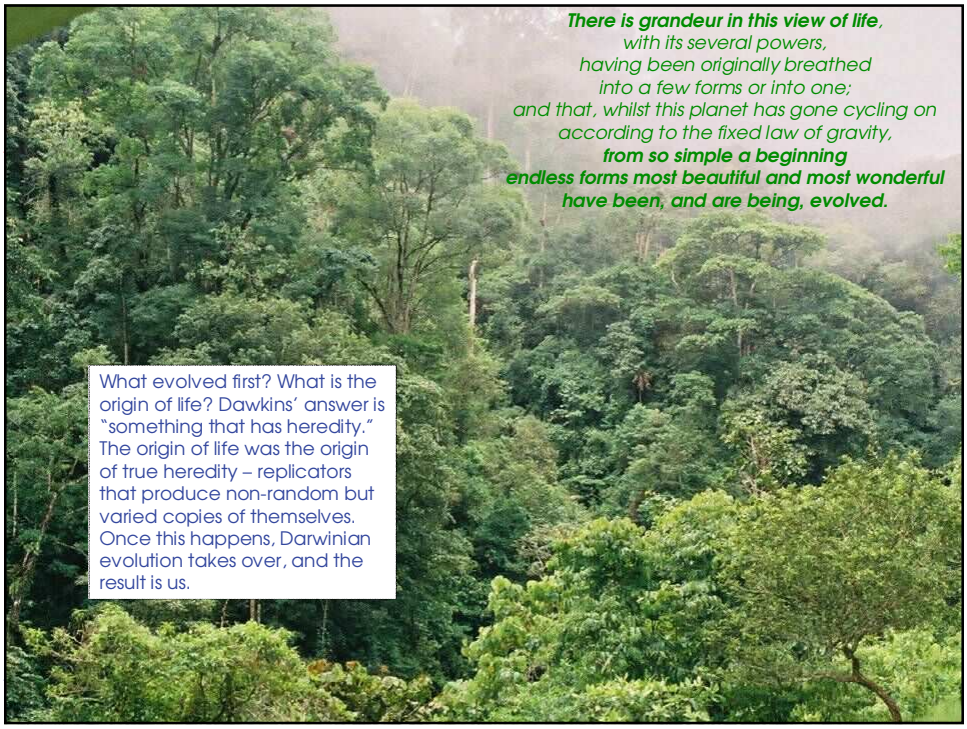


The Final Irony: It’s a DNA World

One view of evolution is that it is not organisms, but DNA, that form the proper unit of study. Humans are temporary vessels containing a mix of evolved genes from different sources. As Dawkins puts it:

An itinerant selfish gene
Said “Bodies aplenty I’ve seen.
You think you’re so clever
But I’ll live forever
You’re just a survival machine.”





Further exploration

Richard Dawkins, *The Ancestor's Tale*
Matt Ridley, *Genome*
Richard Fortey, *Life*

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