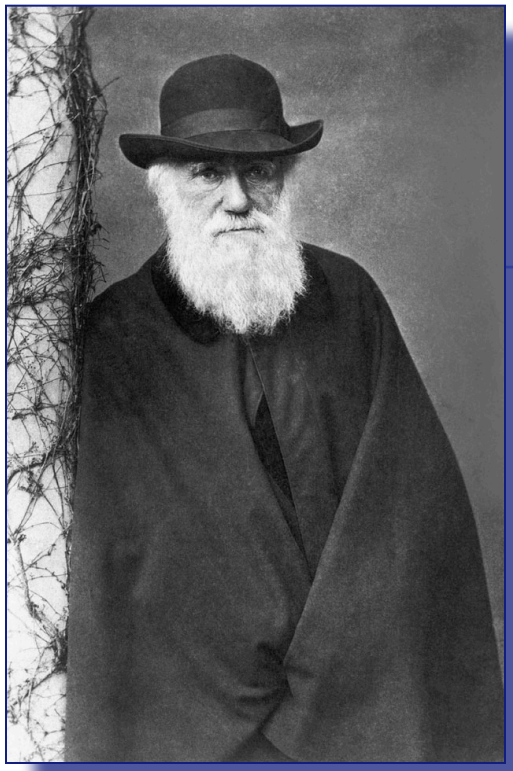


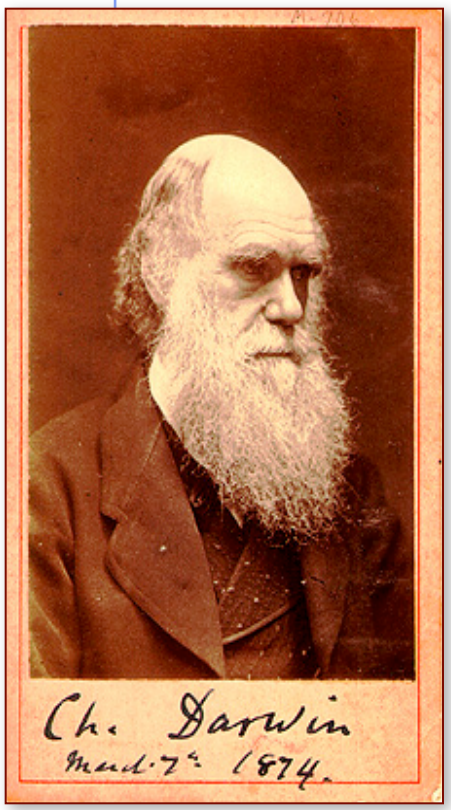
evolution

a journey into where we're from
and where we're going

Evidence of Evolution by Natural Selection

Dodo bird

Essence of Darwin's ideas



(1) Variation exists in natural populations

(2) Many more offspring are born each season than can possibly survive to maturity

(3) As a result, there is a struggle for existence = competition

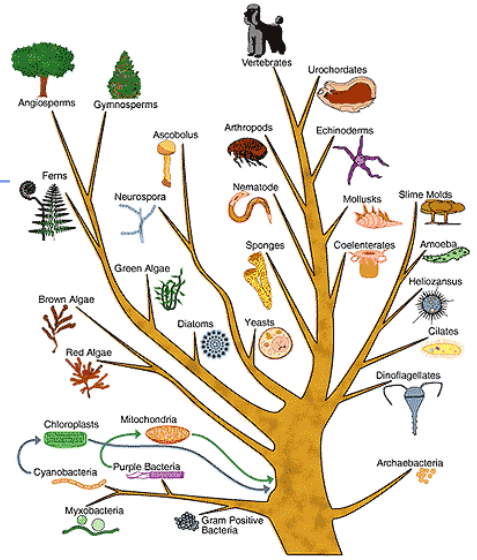
(4) Characteristics beneficial in the struggle for existence will tend to become more common in the population, changing the average characteristics of the population

- these are the adaptations, which help a species survive and, therefore, reproduce.

(5) Over long periods of time, and given a steady input of new variation into a population, these processes lead to the emergence of new species

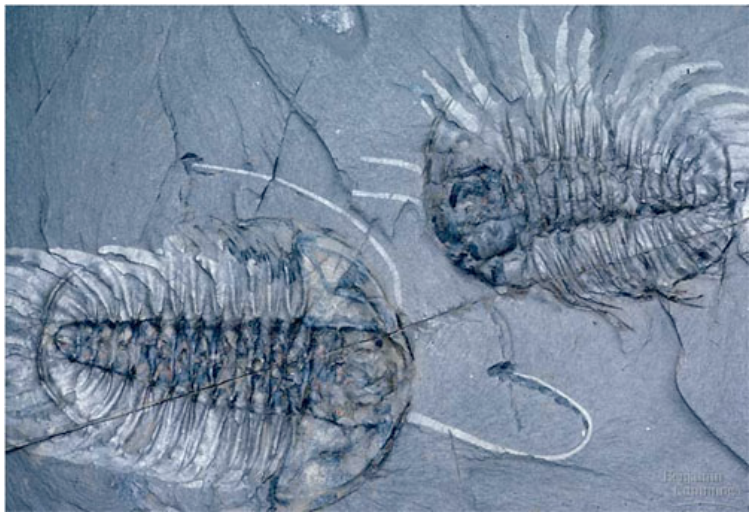
Evidence supporting evolution

1. **Fossil record**
   - transition species
2. **Anatomical record**
   - homologous & vestigial structures
   - embryology & development
3. **Molecular record**
   - shared genetic code
   - homologous protein & DNA sequence
4. **Artificial selection**
   - human-caused evolution
5. **Direct Observation of evolution**
6. **Biogeography**
   - distribution of species



Fossil record

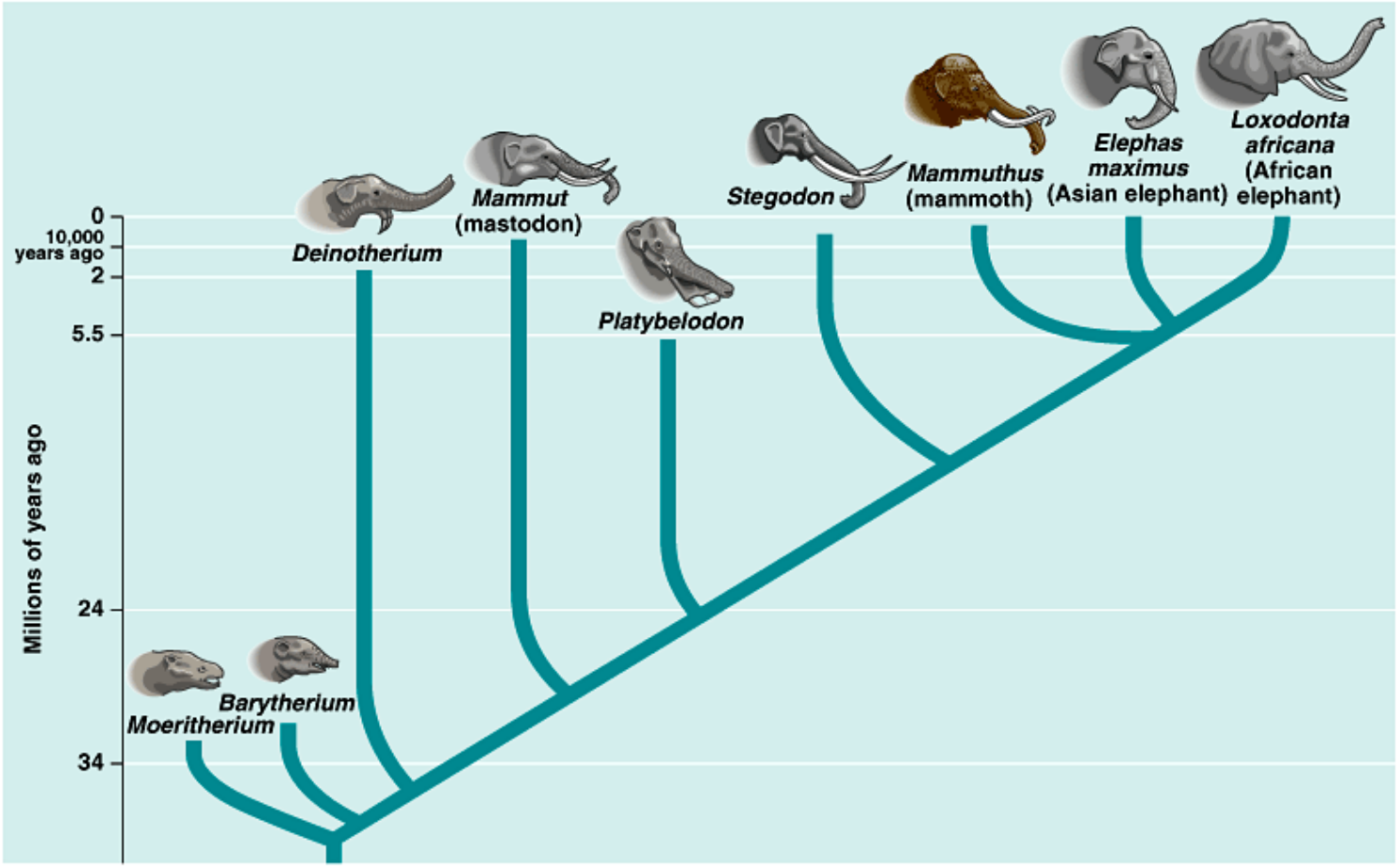
- **Layers of sedimentary rock contain fossils**
  - new layers cover older ones, creating a record over time
  - **The fossil record provides snapshots of the past that, when assembled, illustrate a panorama of evolutionary change over the past four billion years.**
    - fossils within layers show that a succession of organisms have populated Earth throughout a long period of time
  - **The "picture" may be faded in places and may have bits missing, but fossil evidence clearly shows that life is old and has changed over time and more evidence keeps being added.**



AP

Fossil record

- A record showing us that today's organisms descended from ancestral species



Transitional forms

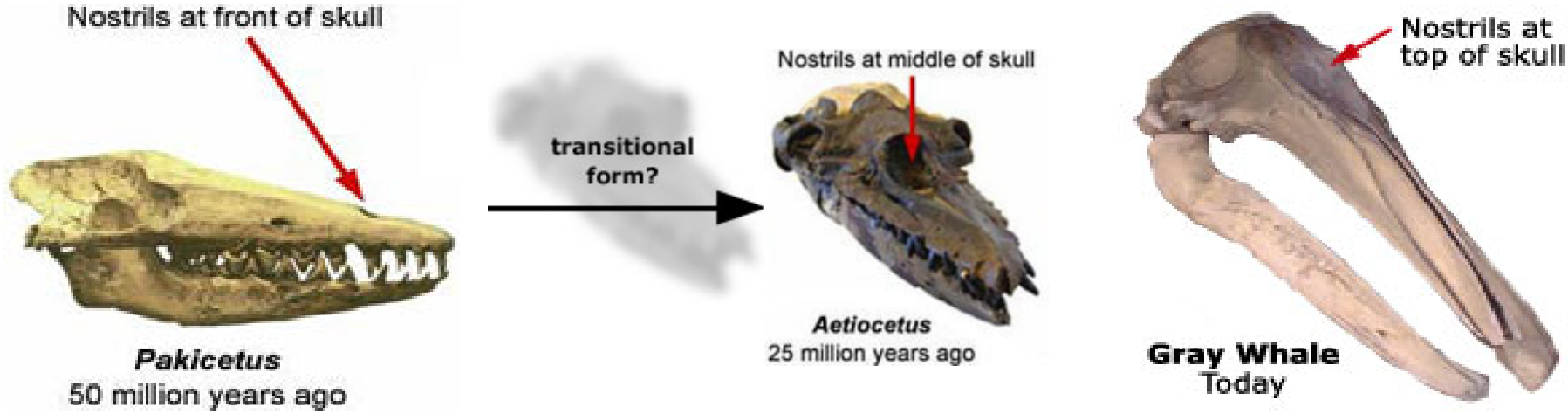
Transitional forms = Fossils or organisms that show the intermediate states between an ancestral form and that of its descendants are referred to as transitional forms.

- **There are numerous examples of transitional forms in the fossil record, providing an abundance of evidence for change over time.**

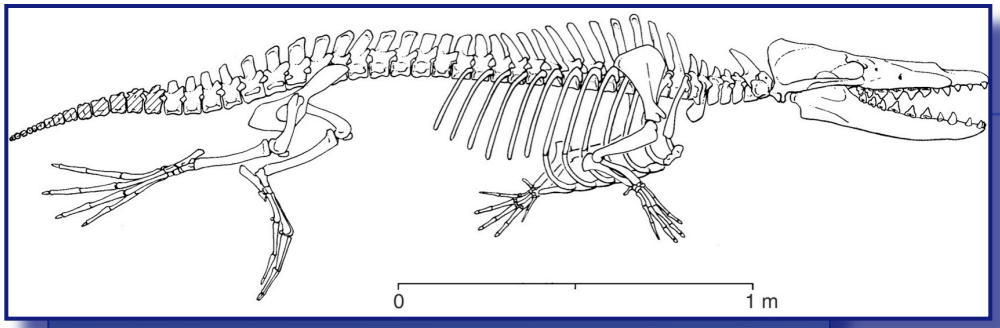
***Pakicetus, a land mammal,* is an early ancestor to modern whales based on a number of specializations of the ear, relating to hearing. The skull shown here displays nostrils at the front of the skull.**

A skull of the modern gray whale today has its nostrils placed at the top of its skull.

It would appear from these two specimens that the position of the nostril has changed over time and thus we would expect to see intermediate forms.



Note that the nostril placement in *Aetiocetus* is intermediate between the ancestral form *Pakicetus* and the modern gray whale, an excellent example of a transitional form in the fossil record!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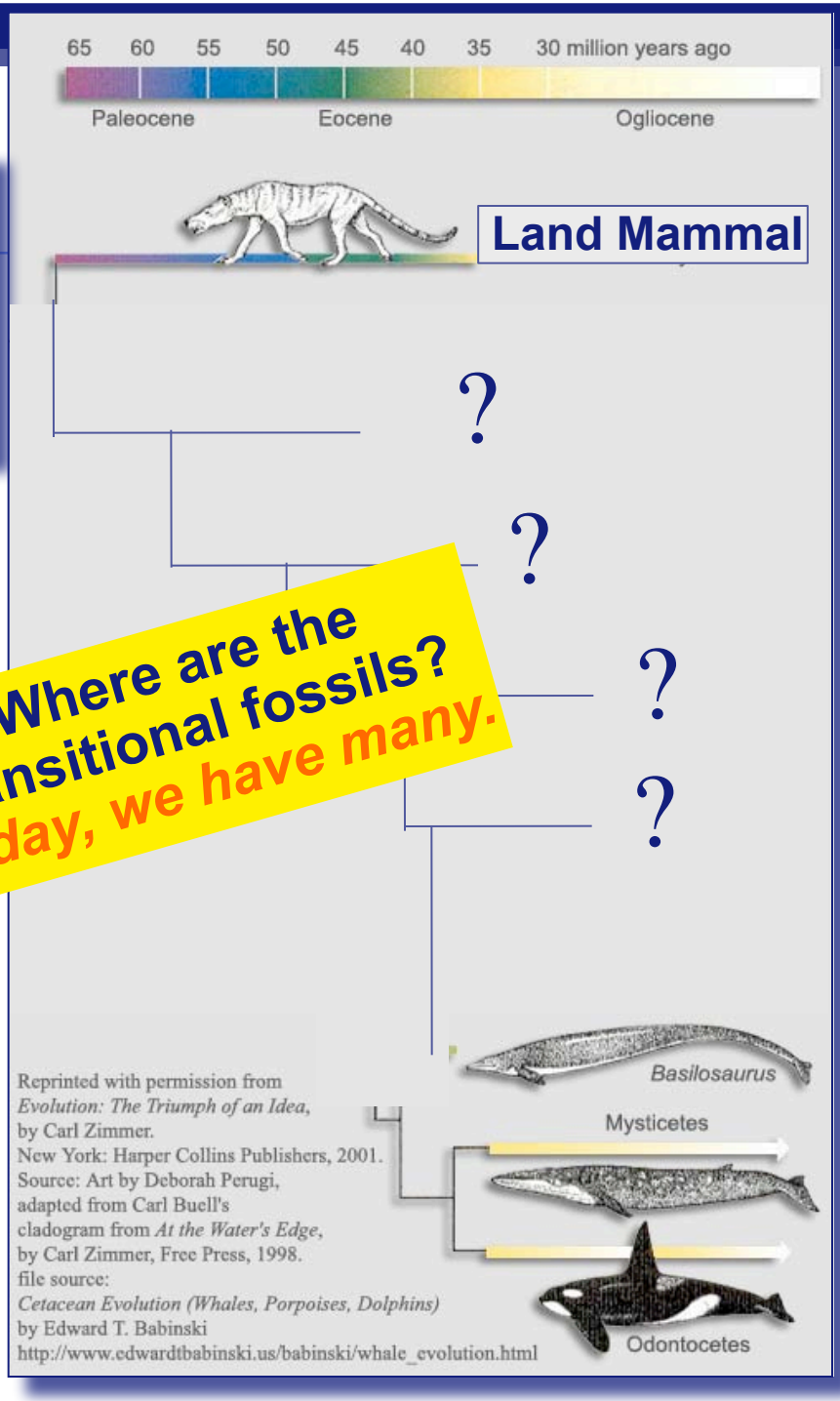
65 60 55 50 45 40 35 30 million years ago
Paleocene
Eocene
Ogliocene
Land Mammal
?
?
?
?
Where are the transitional fossils?
Today, we have many.
Basilosaurus
Mysticetes
Odontocetes
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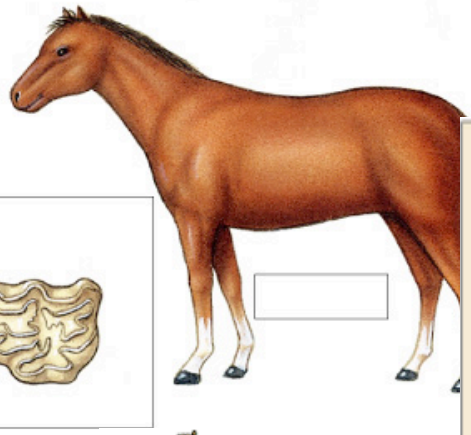
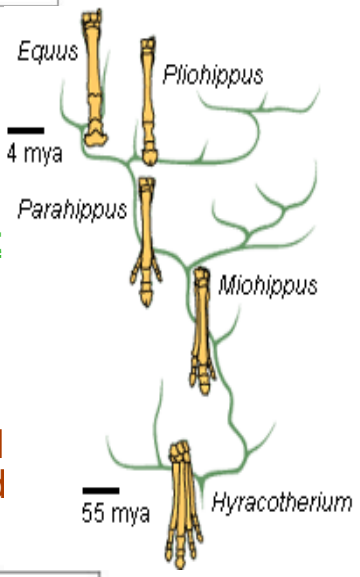
Evolution: The Triumph of an Idea,
by Carl Zimmer.
New York: Harper Collins Publishers, 2001.
Source: Art by Deborah Perugi,
adapted from Carl Buell's
cladogram from *At the Water's Edge*,
by Carl Zimmer, Free Press, 1998.
file source:
Cetacean Evolution (Whales, Porpoises, Dolphins)
by Edward T. Babinski
http://www.edwardtbabinski.us/babinski/whale_evolution.html

Evolutionary change in horses



The four-toed foot of *Hyracotherium*, became the single-toed foot of *Equus*:
Fossils show that the transitional forms predicted by evolution did indeed exist.

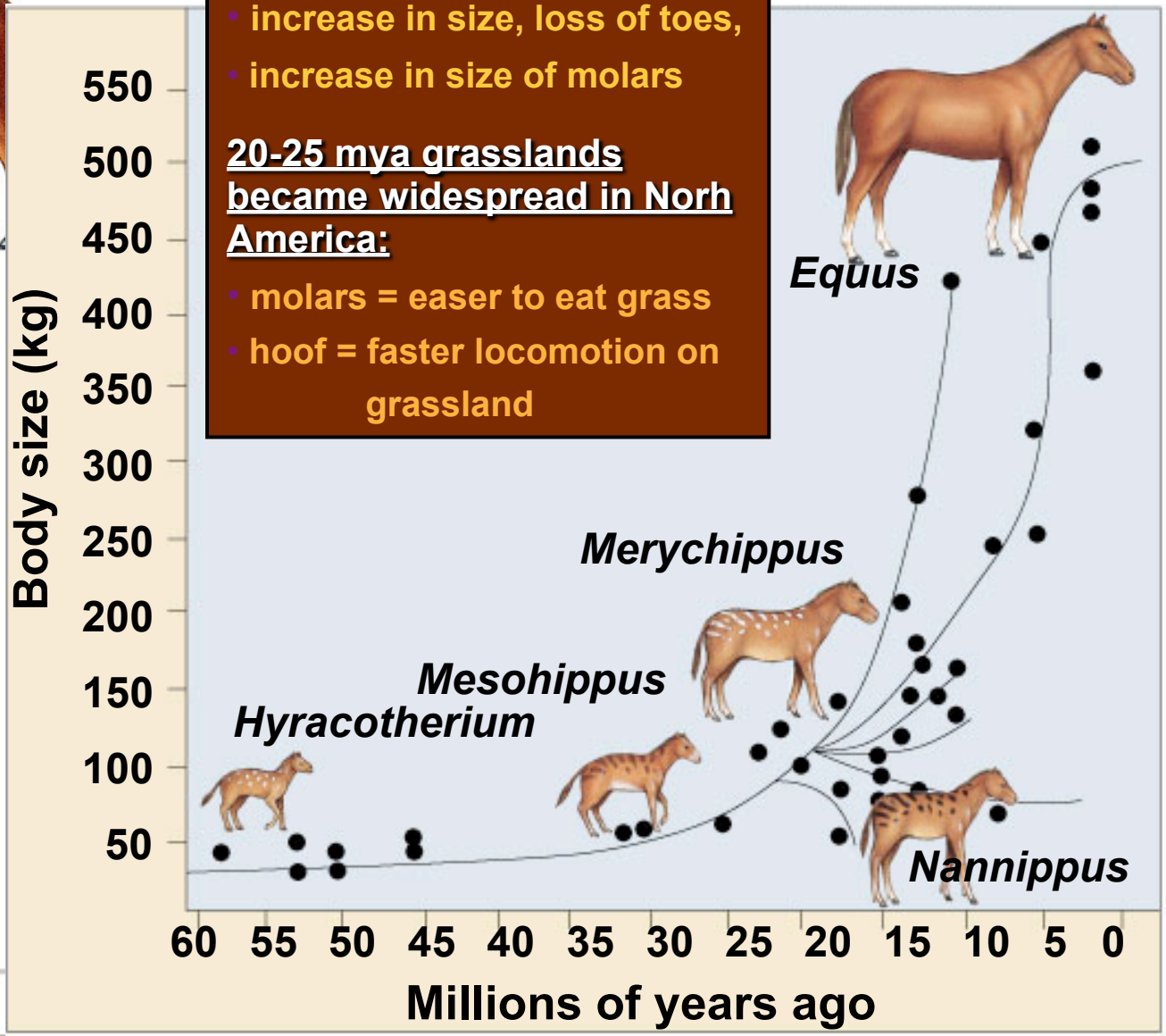


In fossils see:

- increase in size, loss of toes,
- increase in size of molars

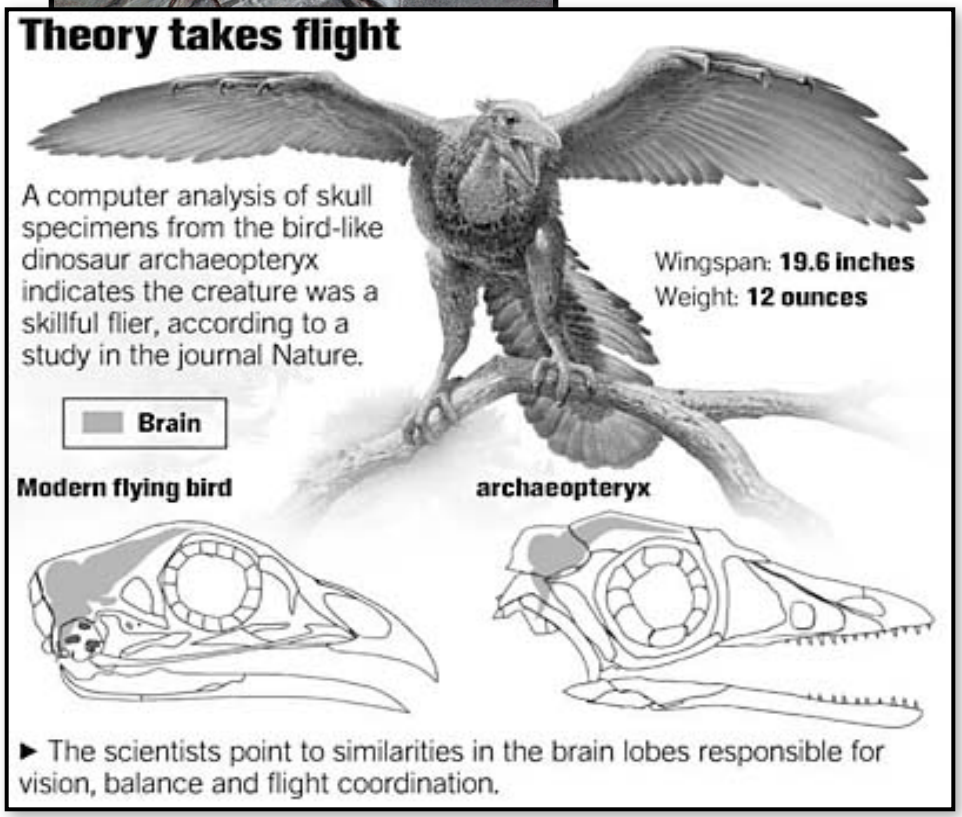
20-25 mya grasslands became widespread in Norh America:

- molars = easer to eat grass
- hoof = faster locomotion on grassland



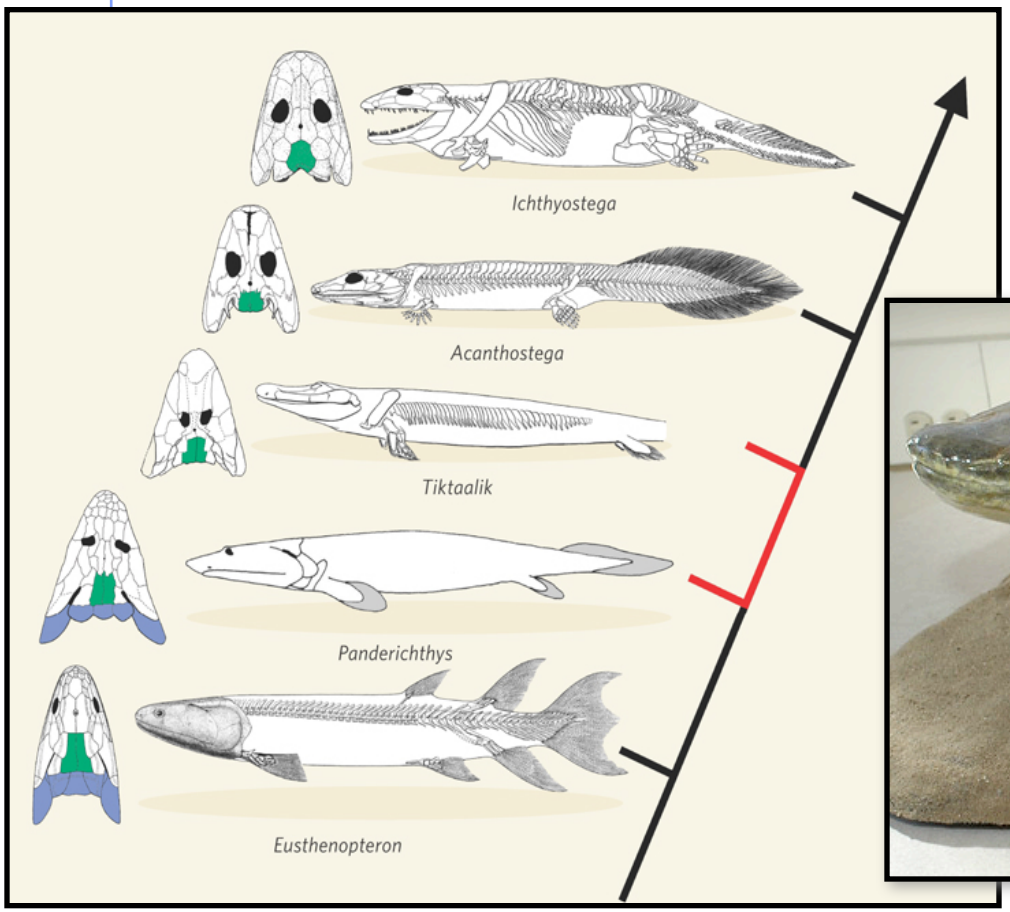
Evolution of birds

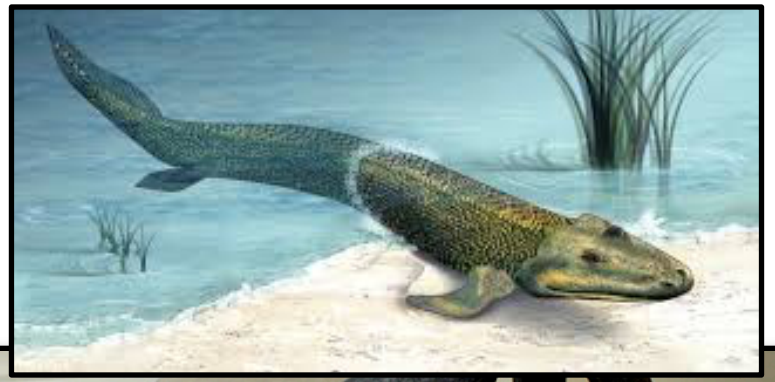
- ***Archaeopteryx***
  - lived about 150 mya
  - This fossil is the 'missing link' between reptiles & birds
    - many shared primitive characters with more basal coelurosaurian dinosaurs (the clade including all theropods more bird-like than Allosaurus), such as teeth, a long bony tail and pinnate feather
      - Yet, had asymmetrical flight feathers on its wings and tail, together with a wing feather arrangement shared with modern birds
      - And resembled modern birds in the dominance of the sense of vision and in the possession of expanded auditory and spatial sensory perception in the ear



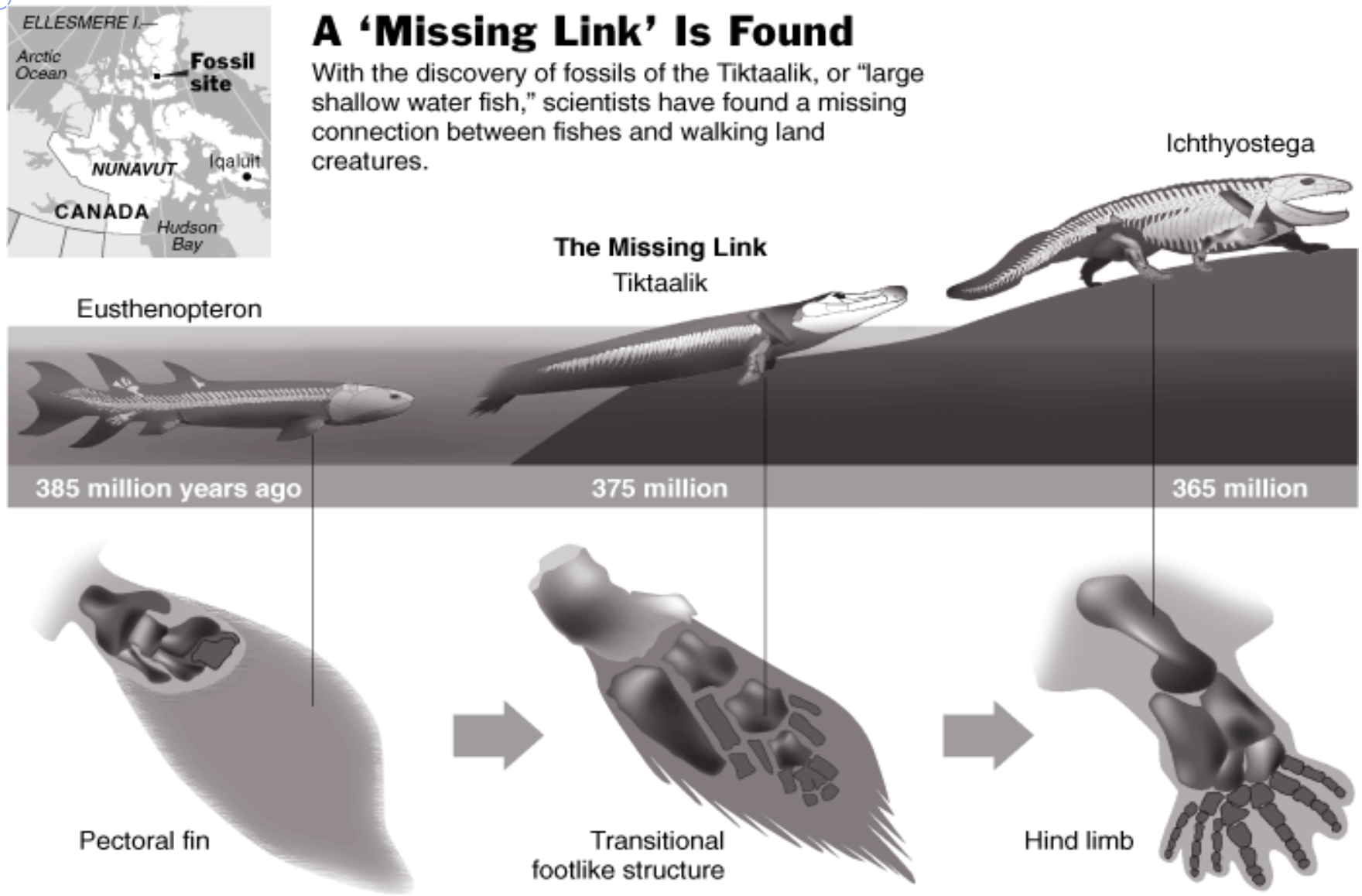
2006 Fossil Discovery of Early Tetrapod

- **Tiktaalik**
  - **the "missing link" from sea to land animals, all vertebrate tetrapods**





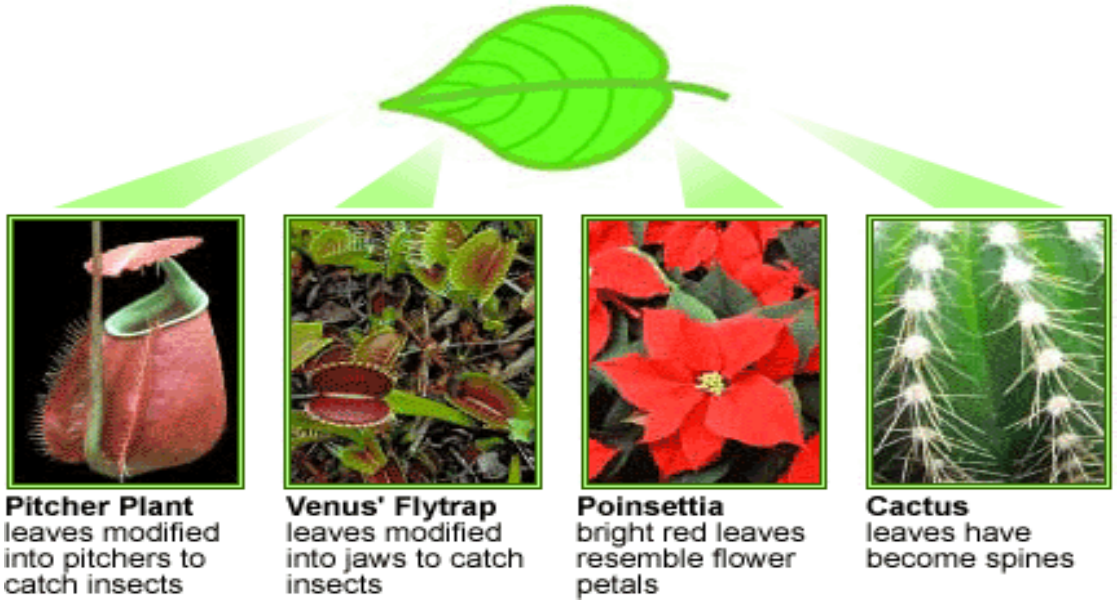
2006 Fossil Discovery of Early Tetrapod



AP

Homologous Structures as Evidence for Evolution

- Evolutionary theory predicts that related organisms will share similarities that are derived from common ancestors.
  - Similar characteristics due to relatedness are known as homologies.
    - Revealed by comparing:
      - the anatomies of different living things
      - looking at cellular similarities and difference
      - studying embryological development
      - studying vestigial structures within individual organisms.



Each leaf has a very different shape and function, yet all are homologous structures, derived from a common ancestral form.

Homologous structures

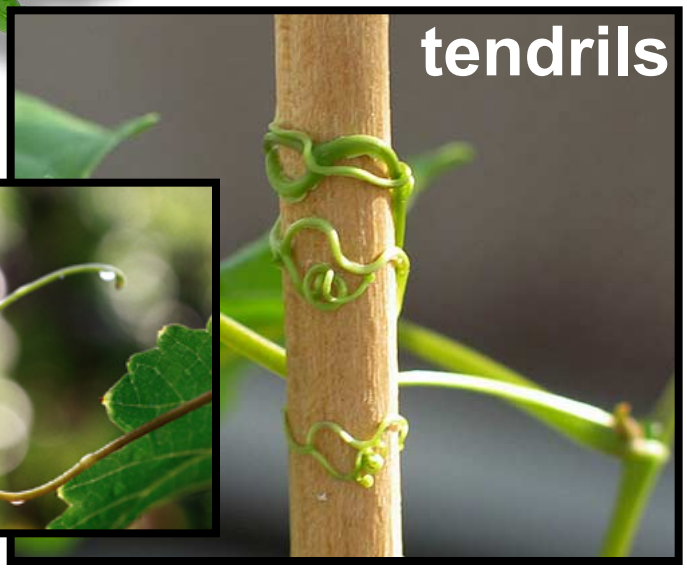
spines

leaves

needles

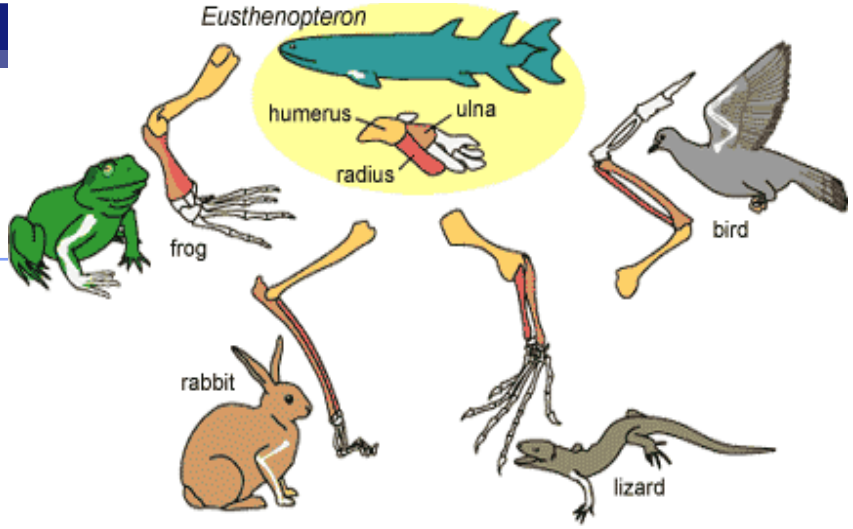
succulent leaves

colored leaves

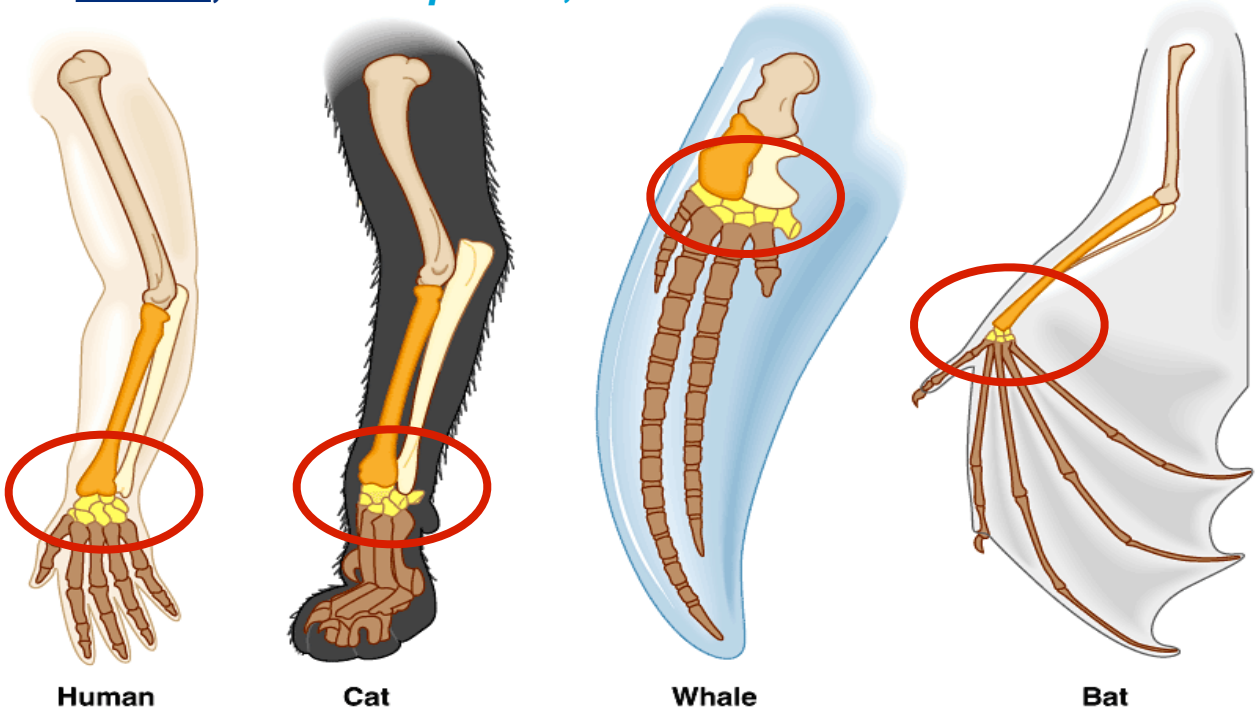


tendrils

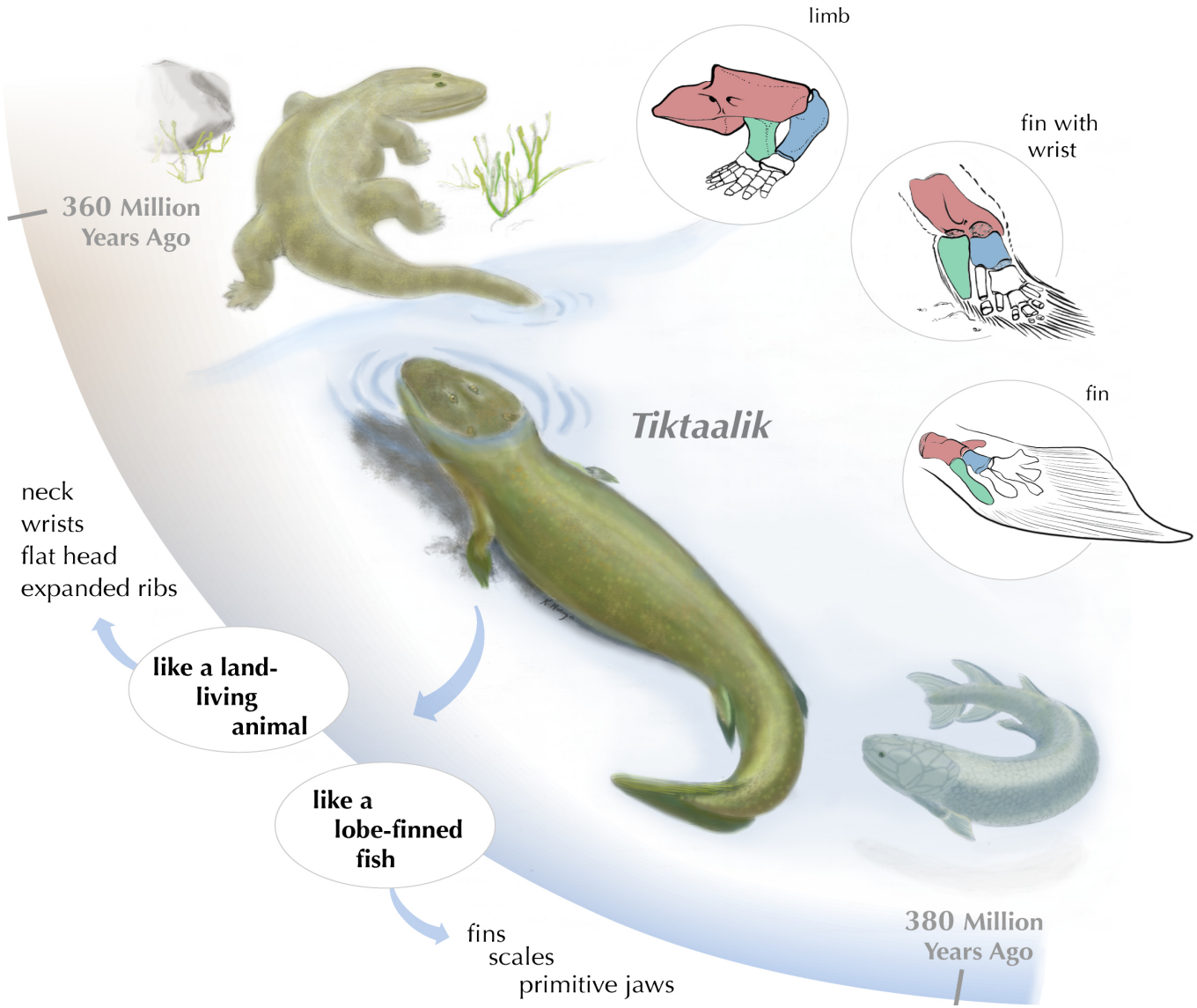
Anatomical record



- **Homologous structures**
  - **similarities in characteristics resulting from common ancestry**
    - **Ex: Forelimbs of mammals have become adapted for different functions but they are constructed from the same basic skeletal elements.**
      - **These are the same bones seen in fossils of the extinct transitional animal, *Eusthenopteron*, which demonstrates their common ancestry.**



Tiktaalik is the source of modern day tetrapods' extremity homologous structures

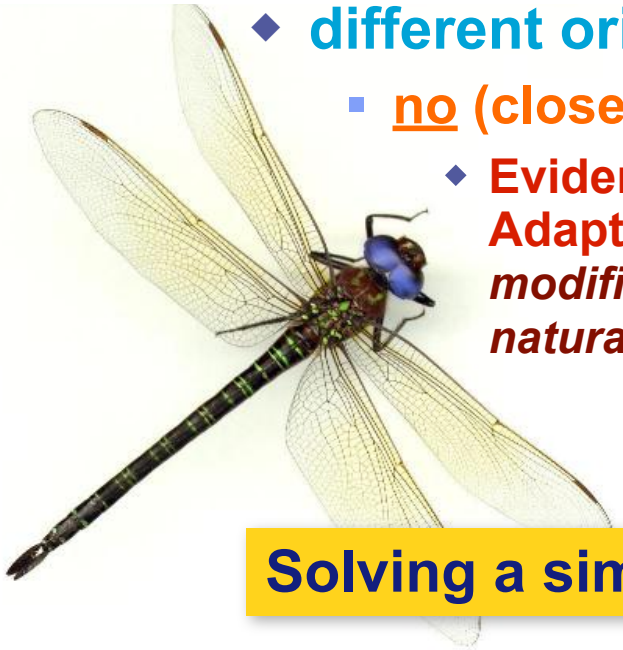


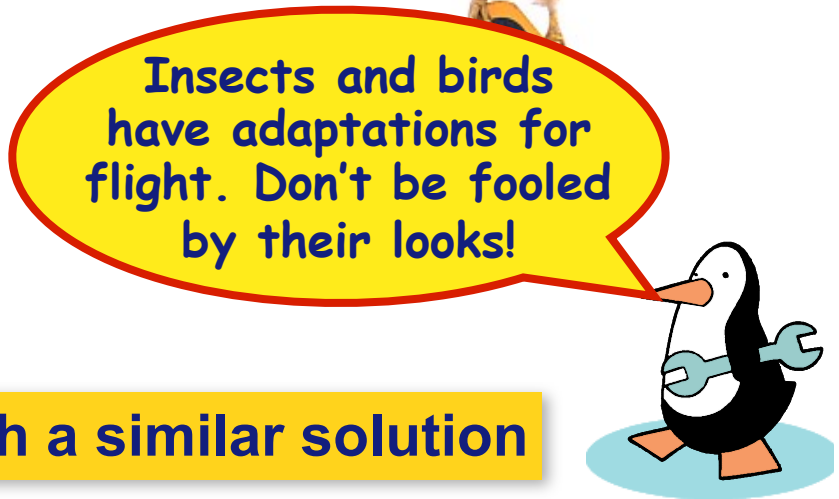
Homologous structures

- Similar structure
- Similar development
- Different functions
  - Evidence of close evolutionary relationship
    - ‘recent’ common ancestor

Analogous structures

- **Separate independent evolution of similar structures or features in different lineages**
  - similar functions
  - similar external form
  - different internal structure & development
  - different origin
    - no (close) evolutionary relationship
      - Evidence for Evolutionary Adaptations *(Descent with modification over time natural selection)*!

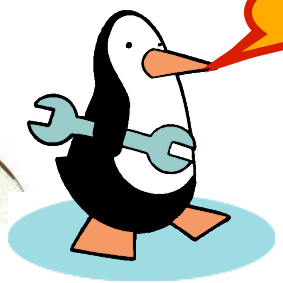




Solving a similar problem with a similar solution

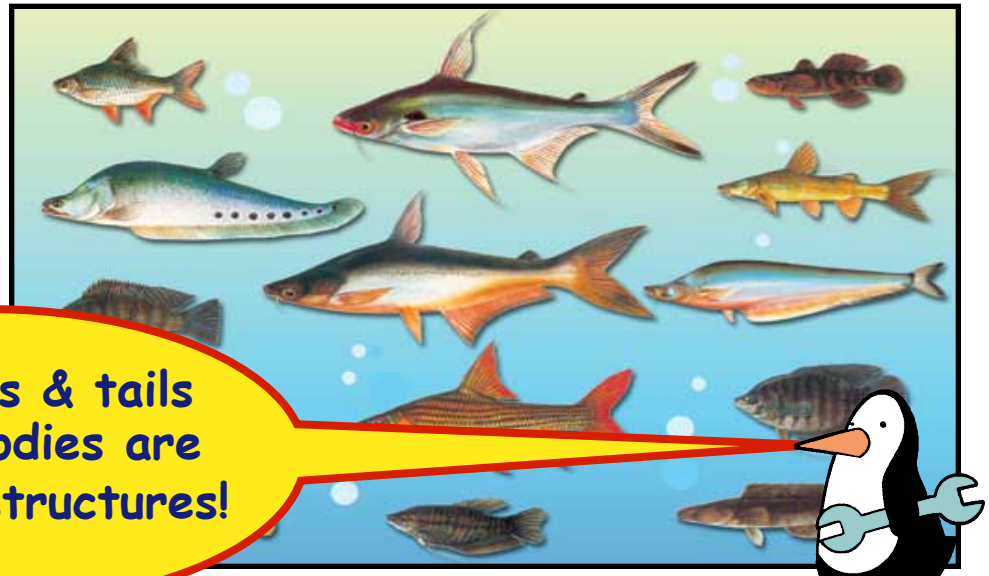
Convergent evolution = the independent evolution of similar features in different lineages

- Flight evolved separately in 3 animal groups
  - evolved similar "solution" to similar "problems"
  - analogous structures



Convergent evolution

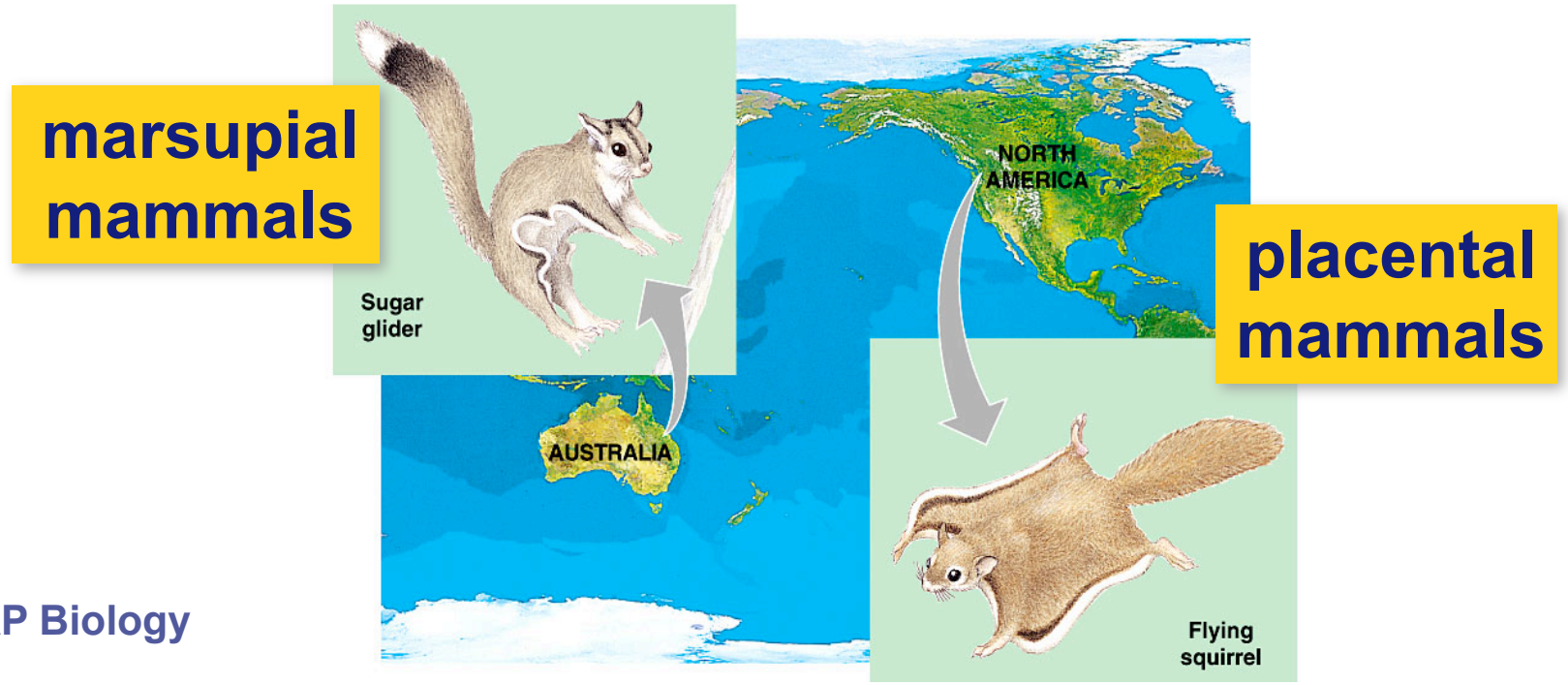
- Fish: aquatic vertebrates *(not tetrapods)*
- Dolphins: aquatic mammals *(tetrapods)*
  - both have similar adaptations to life in the sea
  - NOT closely related organisms though - *their body shape was not inherited from the same common ancestor*



Those fins & tails & sleek bodies are analogous structures!

Convergent Evolution

- Convergent evolution often occurs in common but separate niches
  - filling similar ecological roles in similar environments, so similar adaptations were selected, but the species are not closely related in ancestry
    - The two species evolve from differing starting points in a similar way.
- Another term Parallel Evolution is used when two species evolve similarly from ancestors that were closely related, &, therefore, similar already.
    - The two species evolve from similar starting points in a similar way.

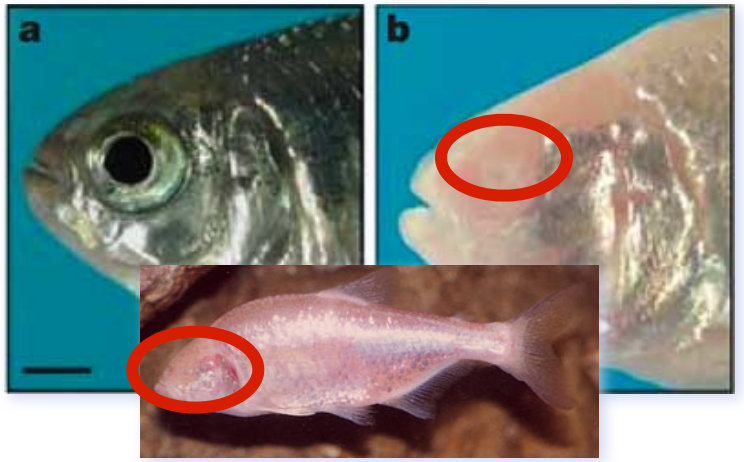


Parallel types across continents

Niche	Placental Mammals	Australian Marsupials
Burrower	 Mole	 Marsupial mole
Anteater	 Anteater	 Numbat
Nocturnal insectivore	 Mouse	 Marsupial mouse
Climber	 Lemur	 Spotted cuscus
Glider	 Flying squirrel	 Sugar glider
Stalking predator	 Ocelot	 Tasmanian cat
Chasing predator	 Wolf	 Tasmanian “wolf”

Vestigial Organs

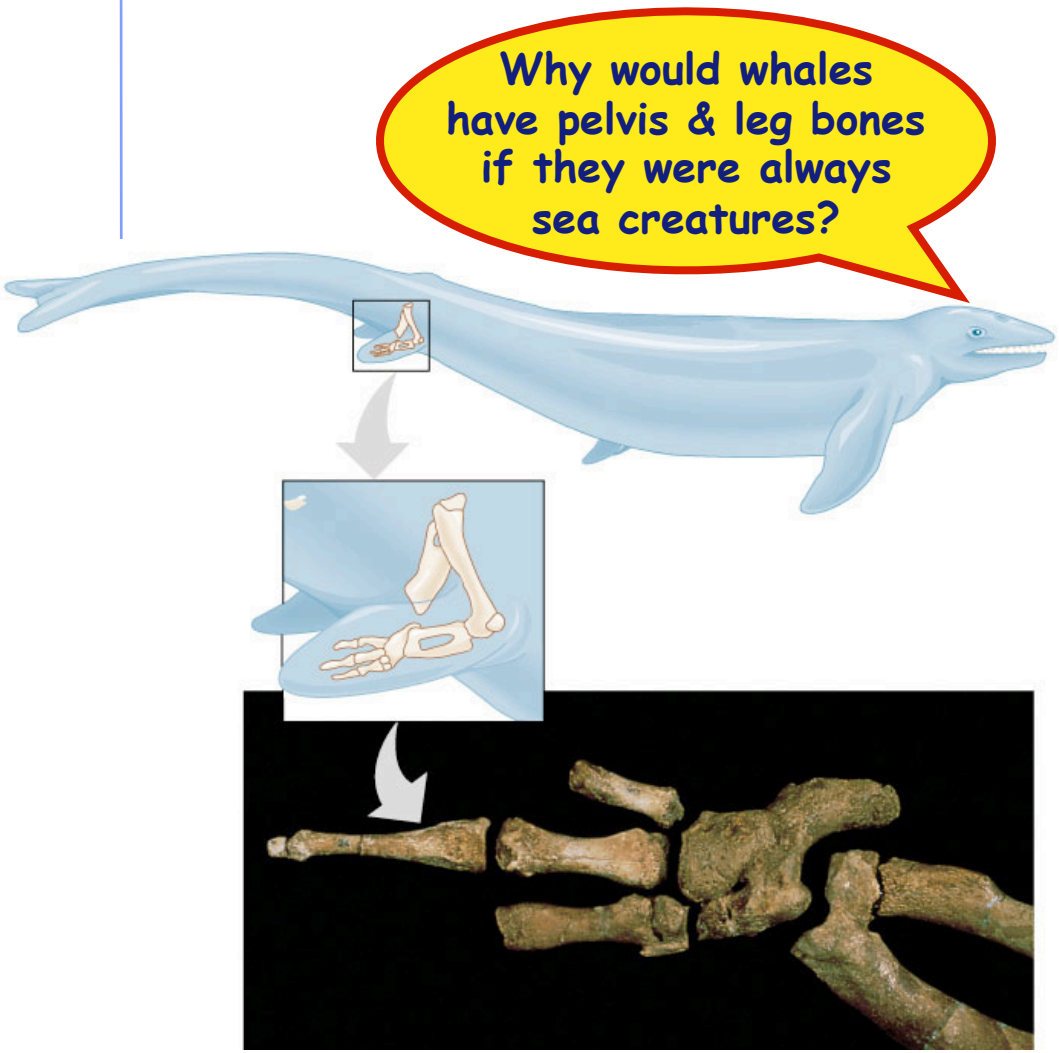
- **Modern animals may have structures that serve little or no function today**
  - these are remnants of structures that were functional in ancestral species
  - **deleterious mutations** that alter phenotype in a "negative" way can accumulate in genes/DNA for non-critical structures *without* reducing fitness sometimes if that phenotype change doesn't affect survivability & reproductive success.
    - snakes & whales — contain the remains of the pelvis & leg bones of walking ancestors
    - eyes on blind cave fish who live in the dark



- human tail bone, a remnant of our primate ancestors

Vestigial Organs

- Hind leg bones on whale fossils



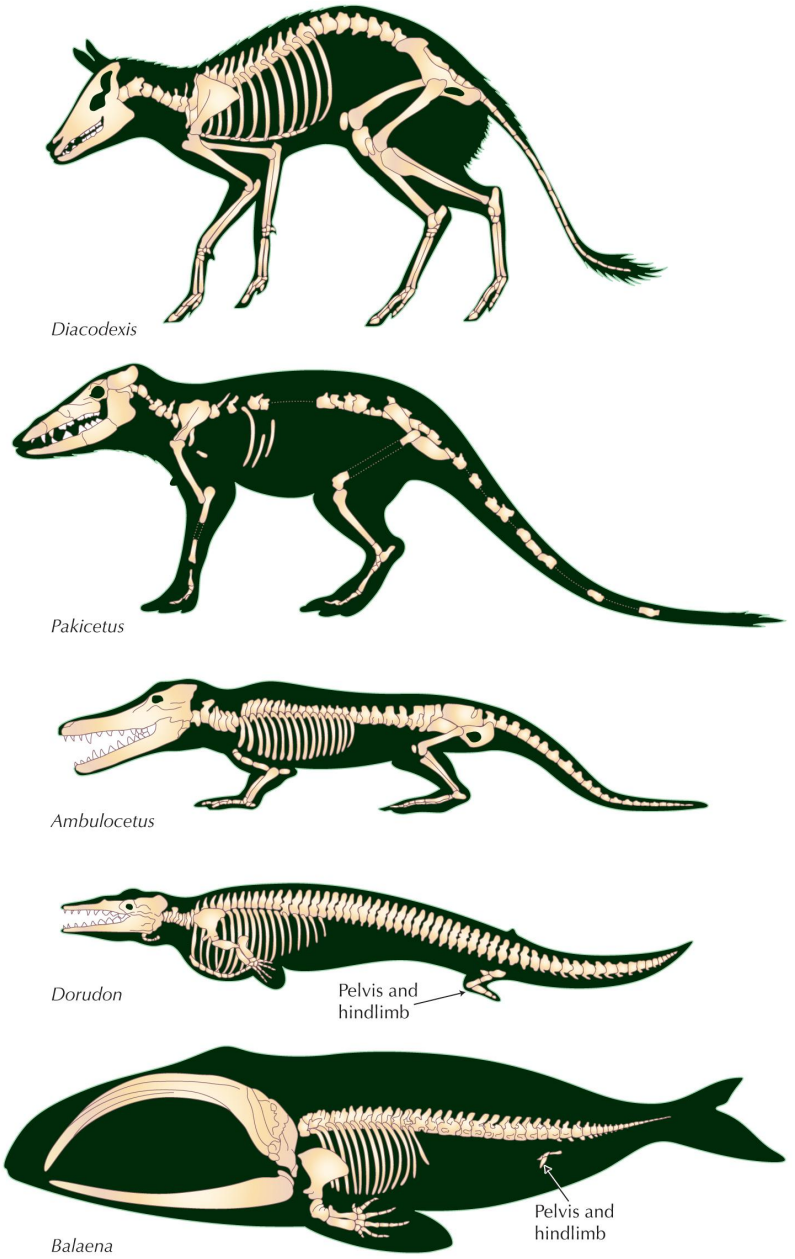
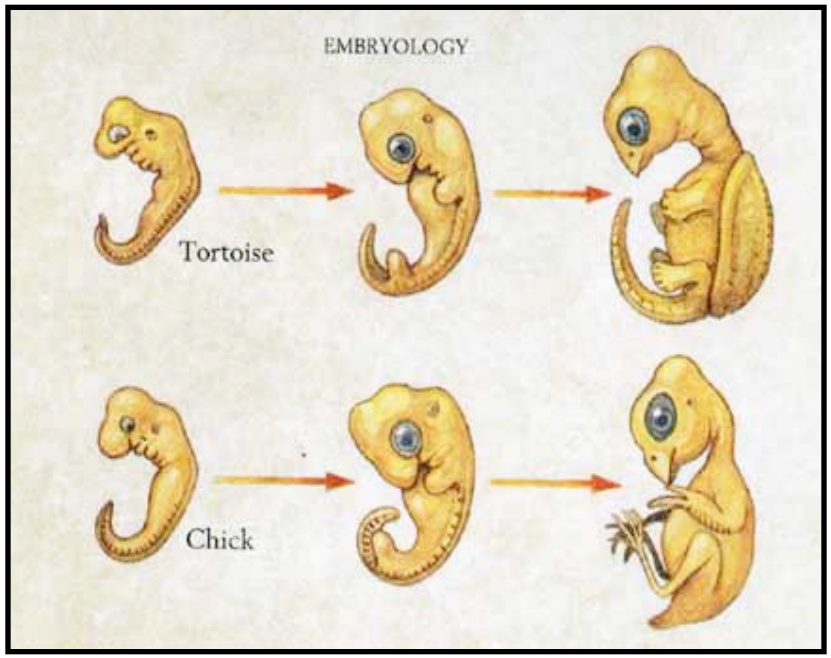
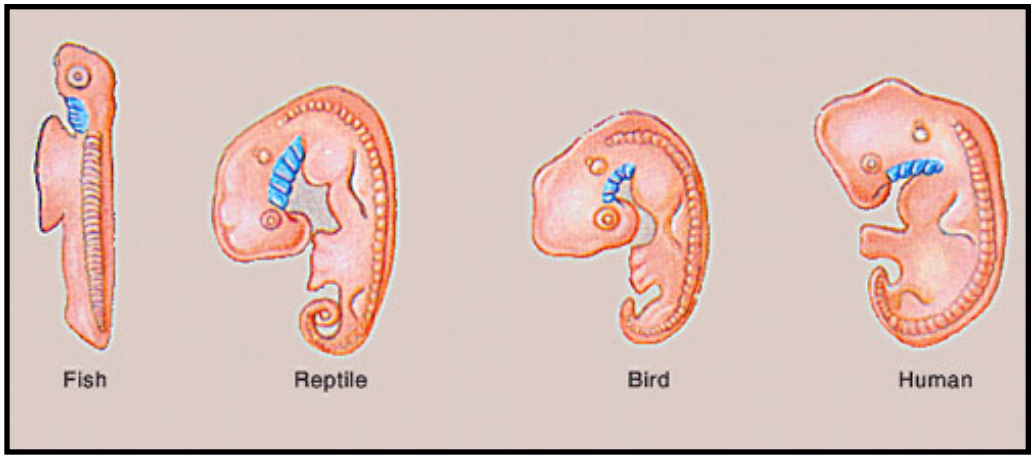


FIGURE 3.18. A series of fossils from the Eocene (~50 Mya) hippo-like artiodactyl (*Diacodexis, top*) to a skeleton of the modern whale (e.g., *Balaena, bottom*) shows how mammals adapted to life in the sea. Among the most important changes, the pelvis and hindlimbs were reduced, the tail was lengthened for swimming, and the jaws were modified for feeding on plankton.

Comparative embryology reveals homologous features present during development.

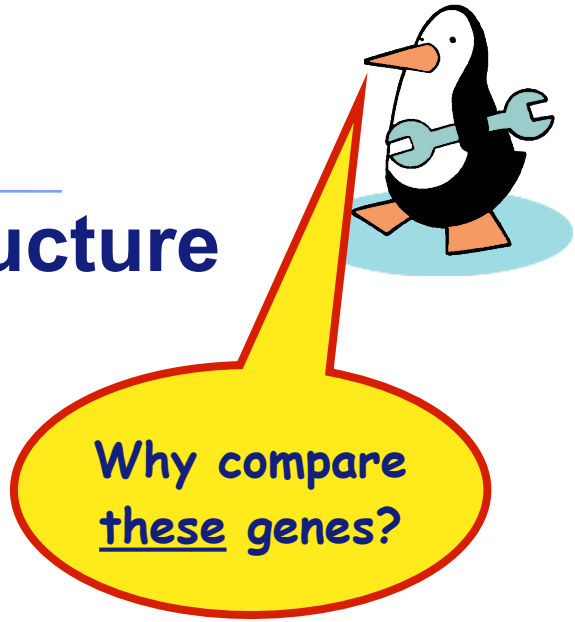
- **Similar embryological development in closely related species**
  - all vertebrate embryos have similar structures at different stages of development
    - gill pouch in fish, frog, snake, birds, human, etc.





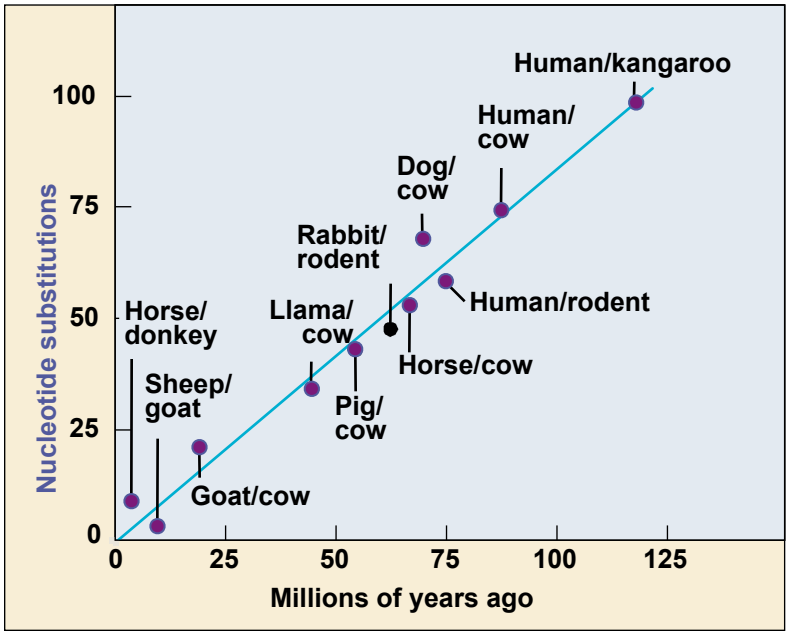
Molecular record

- Comparing DNA & protein structure
  - universal genetic code!
    - compare DNA & RNA
  - compare common genes
    - cytochrome C (respiration)
    - hemoglobin (gas exchange)

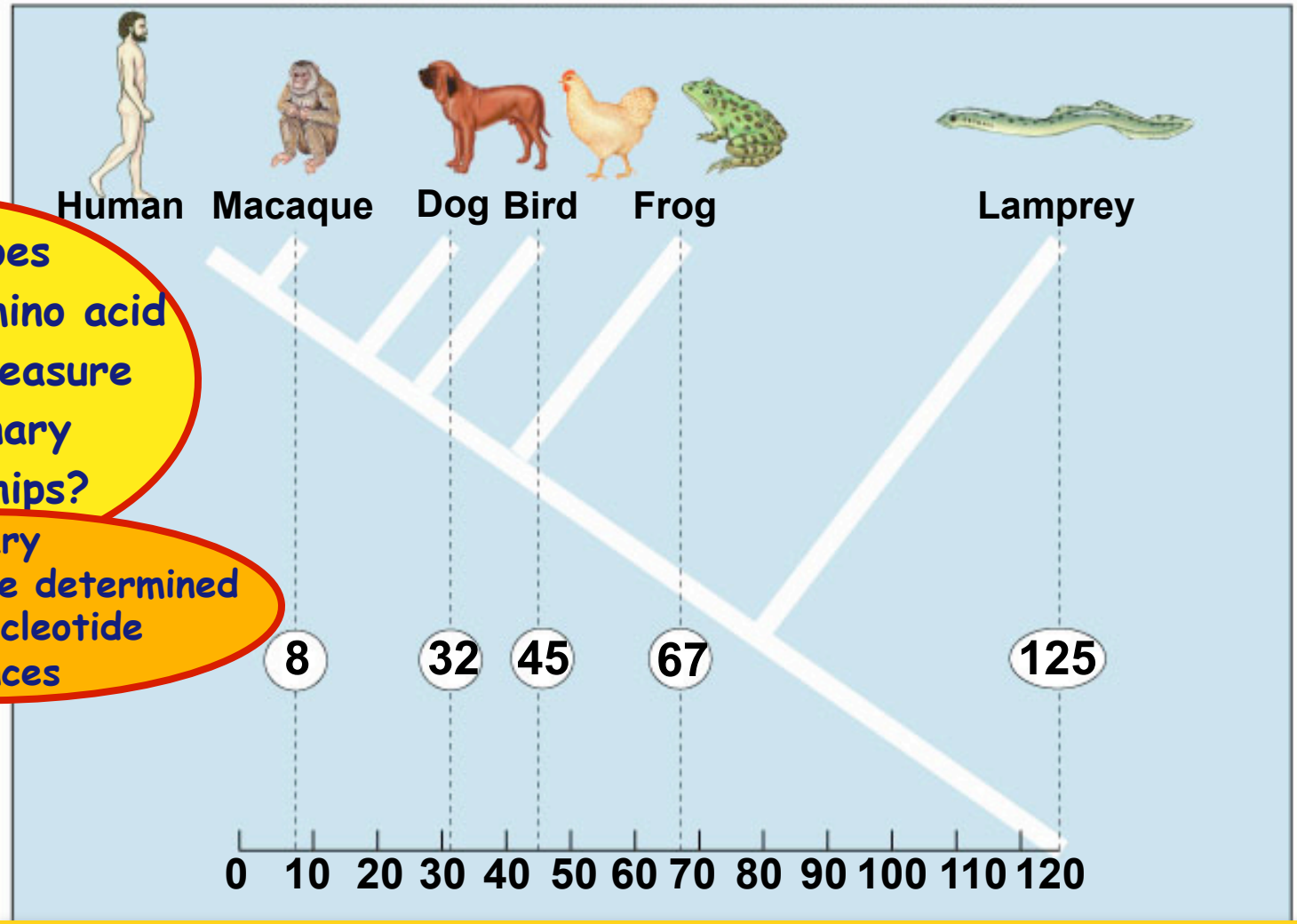


Closely related species have sequences that are more similar than distantly related species

- DNA & proteins are a molecular record of evolutionary relationships



Comparative hemoglobin structure



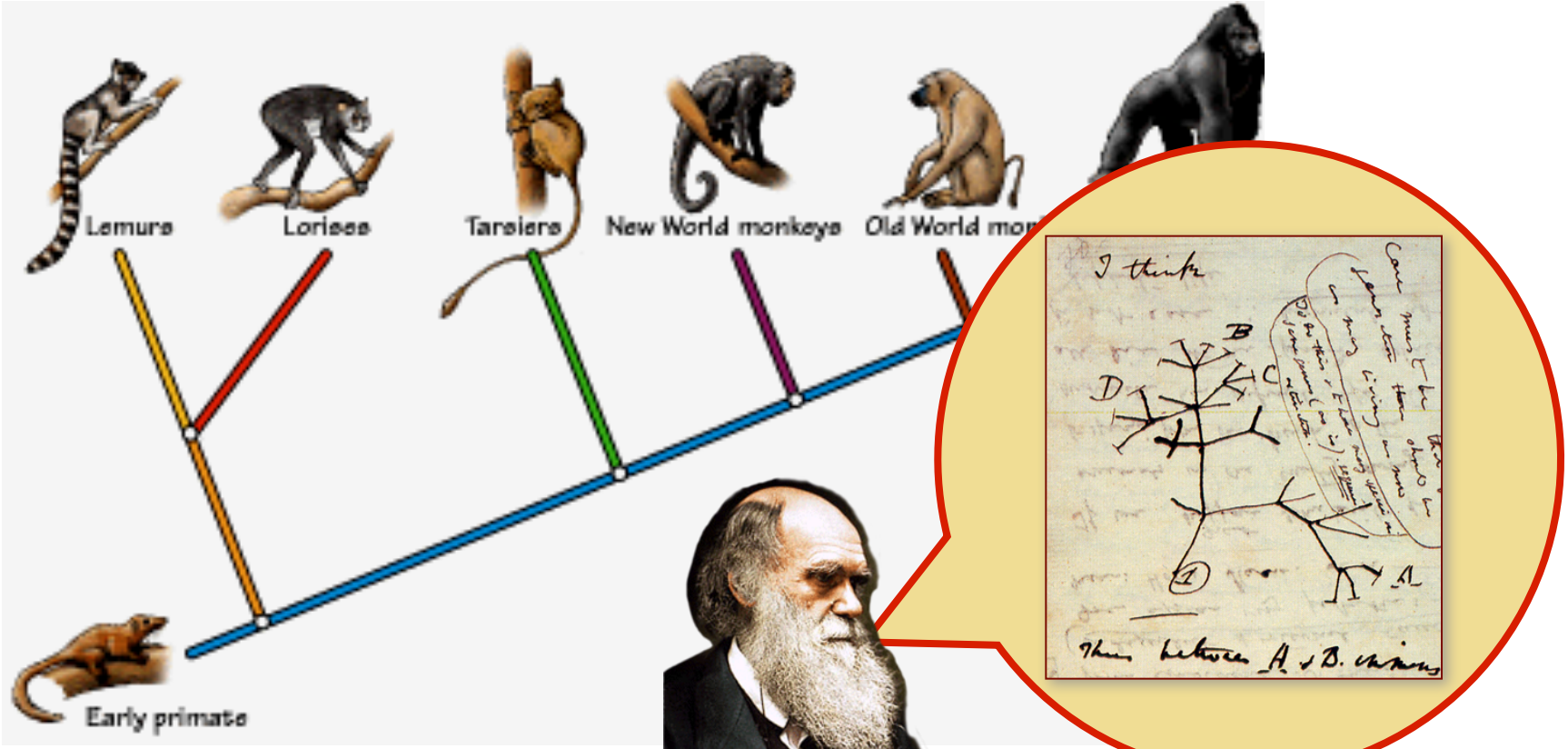
Why does comparing amino acid sequence measure evolutionary relationships?

Primary protein structure determined by DNA nucleotide sequences

Number of amino acid differences between hemoglobin (146 aa) of vertebrate species and that of humans

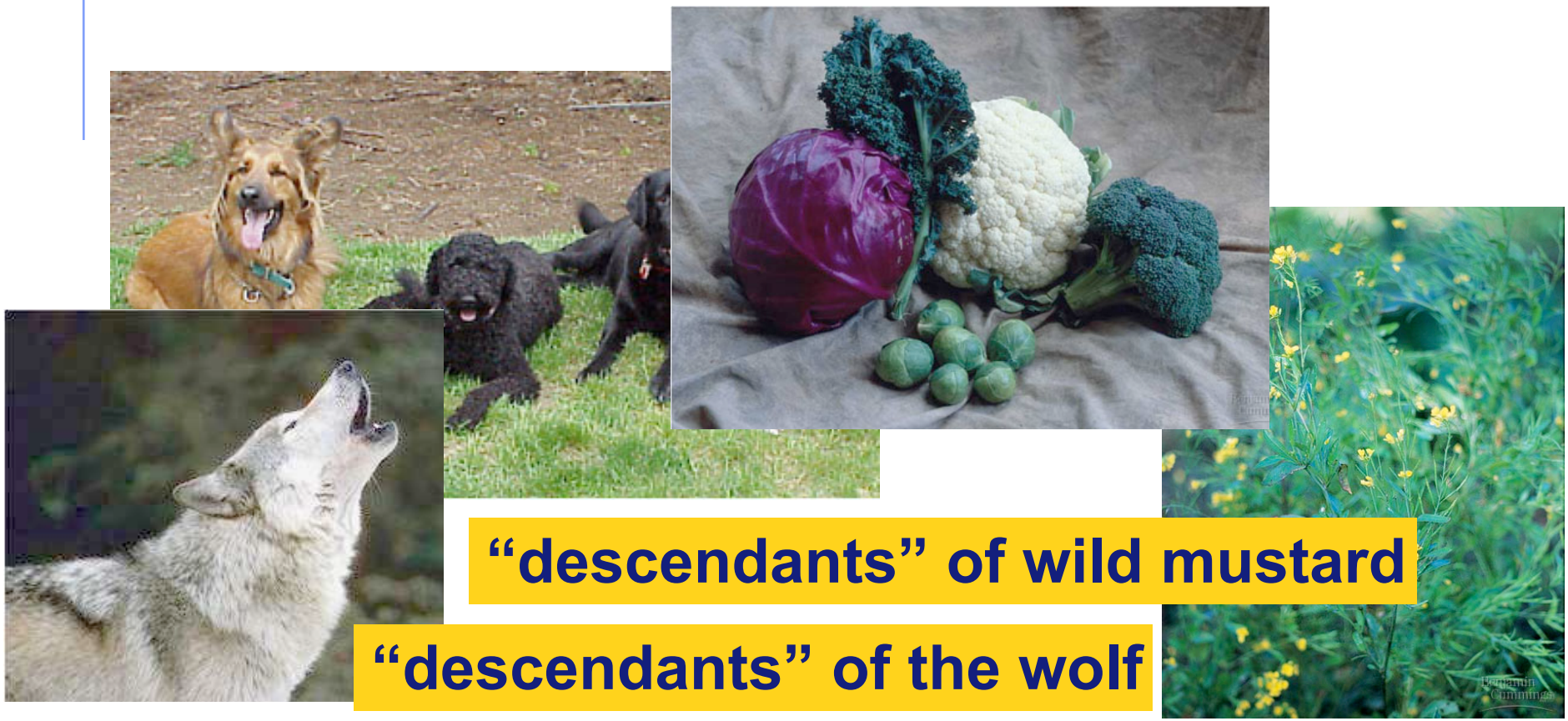
Building “family” trees

Closely related species (branches) share same line of descent until their divergence from a common ancestor



Artificial selection

- Artificial breeding can use variations in populations to create vastly different "breeds" & "varieties"

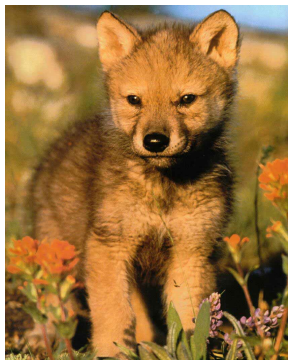


"descendants" of wild mustard

"descendants" of the wolf

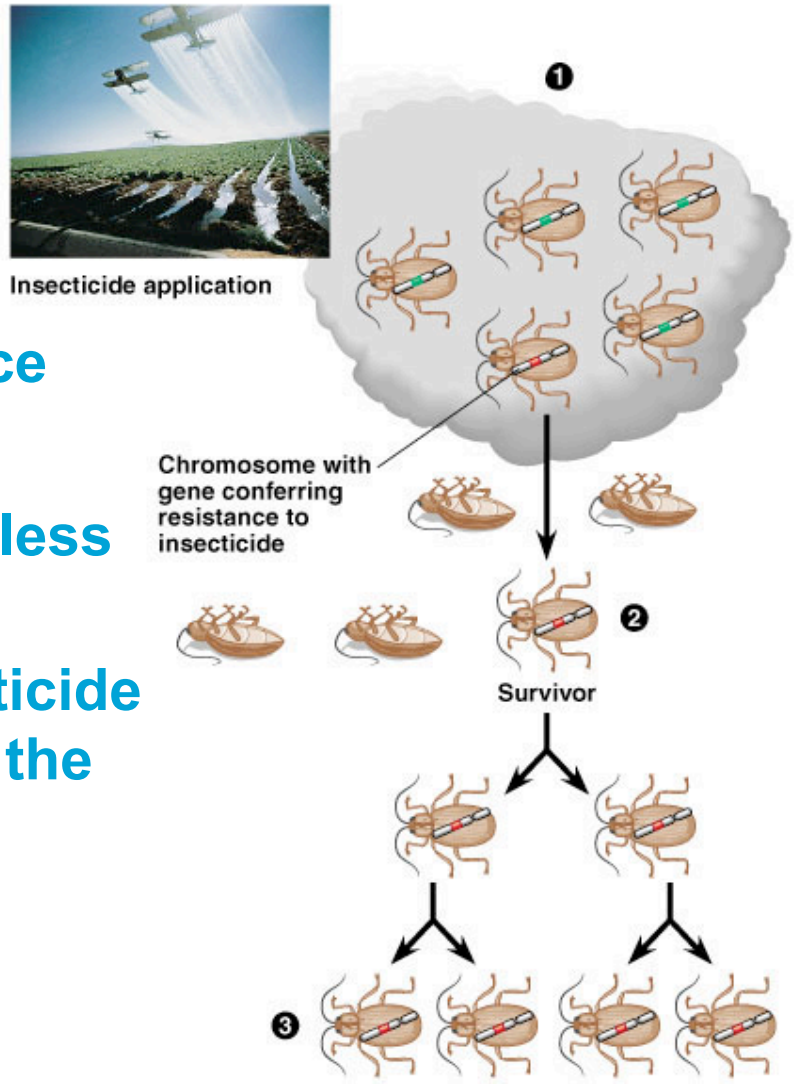
Artificial selection

- People have been artificially selecting domesticated plants and animals for thousands of years.
- These activities have amounted to large, long-term, practical experiments that clearly demonstrate that species can change dramatically through selective breeding.
- Shows that selection has profound effects on populations and has the ability to modify forms and behaviors of living things to the point that they look and act very unlike their ancestors.
- Artificial selection provides a model that helps us understand natural selection.
  - It is a small step to envision natural conditions acting selectively on populations and causing natural changes.



Evidence of Natural selection in action

- **Insecticide & drug resistance**
  - insecticide didn't kill all individuals
  - resistant survivors reproduce
  - resistance is inherited
  - insecticide becomes less & less effective
  - Because the allele for insecticide resistance spreads through the population
    - The population evolved!



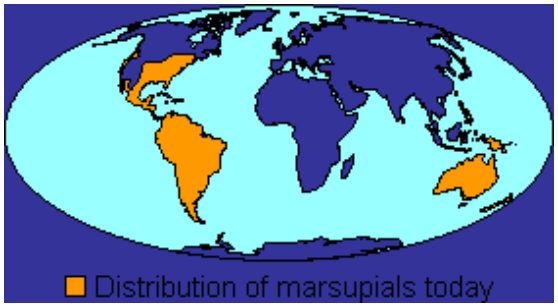
Biogeographical evidence


opossum


+ wallaby

- **Biogeography:** the geographic distribution of species
  - Influenced among other by continental drift, the slow movement of continents over time.
  - Ex: Marsupial mammals are found in the Americas as well as Australia and New Guinea.
    - They are not found swimming across the Pacific Ocean, nor have they been discovered wandering the Asian mainland. There appear to be no routes of migration between the two populations.
    - How could marsupials have gotten from their place of origin to locations half a world away?

Jurassic Period – 160 mya

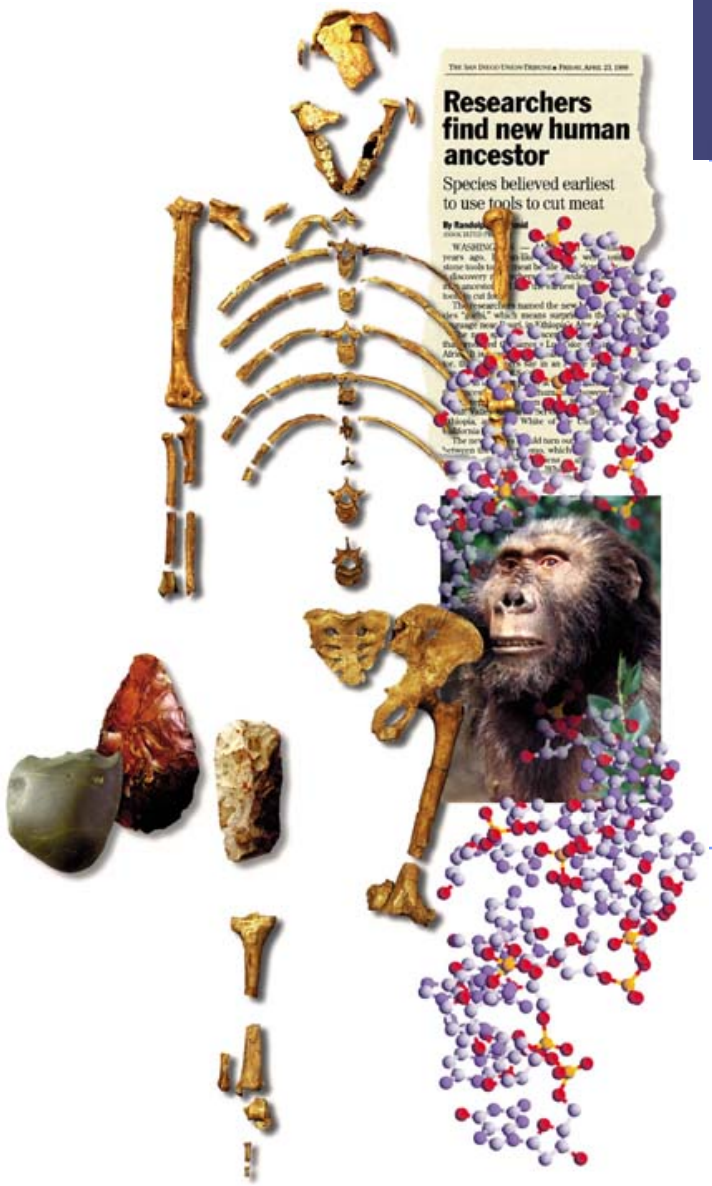


- Fossils of marsupials have been found in the Antarctic as well as in South America and Australia.
- During the past few decades scientists have demonstrated that what is now called South America was part of a large land mass called Gondwana, which included Australia and Antarctica.
  - Gondwana split apart 160 to 90 million years ago.

Marsupials didn't need a migration route from one part of the world to another; they rode the continents to their present positions.

evolution

a journey into where we're from and where we're going



Evidence of Evolution by Natural Selection

Testable Hypotheses

2006-2007

Peppered Moths in England

- Dark vs. light variants



Year	% dark	% light
1848	5	95
1895	98	2
1995	19	81

Peppered Moth in England

- What was the selection factor?
  - early 1800s = pre-industrial England
    - low pollution
    - lichen growing on trees = light colored bark
  - late 1800s = industrial England
    - factories = soot-coated trees
    - killed lichen = dark colored bark
    - Ex. of industrial melanism
  - mid 1900s = pollution controls
    - clean air laws
    - return of lichen = light colored bark

Genome sequencing

- **What can data from whole genome sequencing tell us about evolution of humans?**

Chimp genetic code opens human frontiers

Genome comparison reveals many similarities — and crucial differences

By Alan Boyle
Science editor
MSNBC
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Scientists unleashed a torrent of studies comparing the genetic coding for humans and chimpanzees on Wednesday, reporting that 96 percent of our DNA sequences are identical. Even more intriguingly, the other 4 percent appears to contain clues to how we became different from our closest relatives in the animal kingdom, they said.

"We're really looking at an individual evolutionary event, and this is spectacular," said University of Washington geneticist Robert Waterston, senior author of a study in the journal Nature presenting the draft of the chimpanzee genome.

Primate Common Ancestry?

Chromosome Number in the Great Apes (*Hominidae*)

orangutan *(Pogo)*	48
gorilla *(Gorilla)*	48
chimpanzee *(Pan)*	48
human *(Homo)*	46

Hypothesis:
Change in chromosome number?
If these organisms share a common ancestor, then is there evidence in the genome for this change in chromosome number

Chromosomal fusion

Testable prediction:
If common ancestor had 48 chromosomes (24 pairs), then humans carry a fused chromosome (23 pairs).

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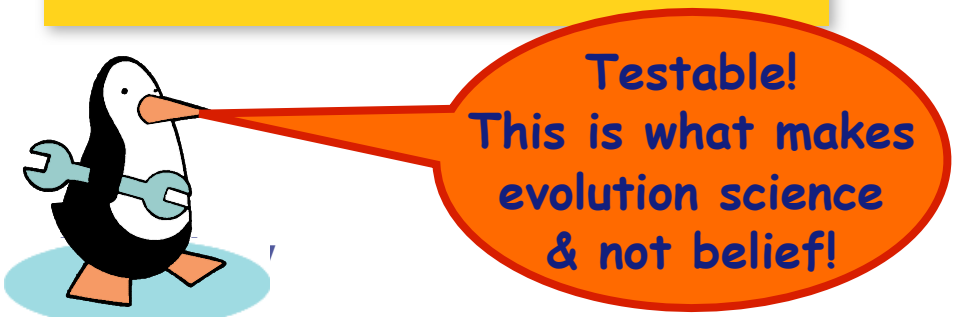
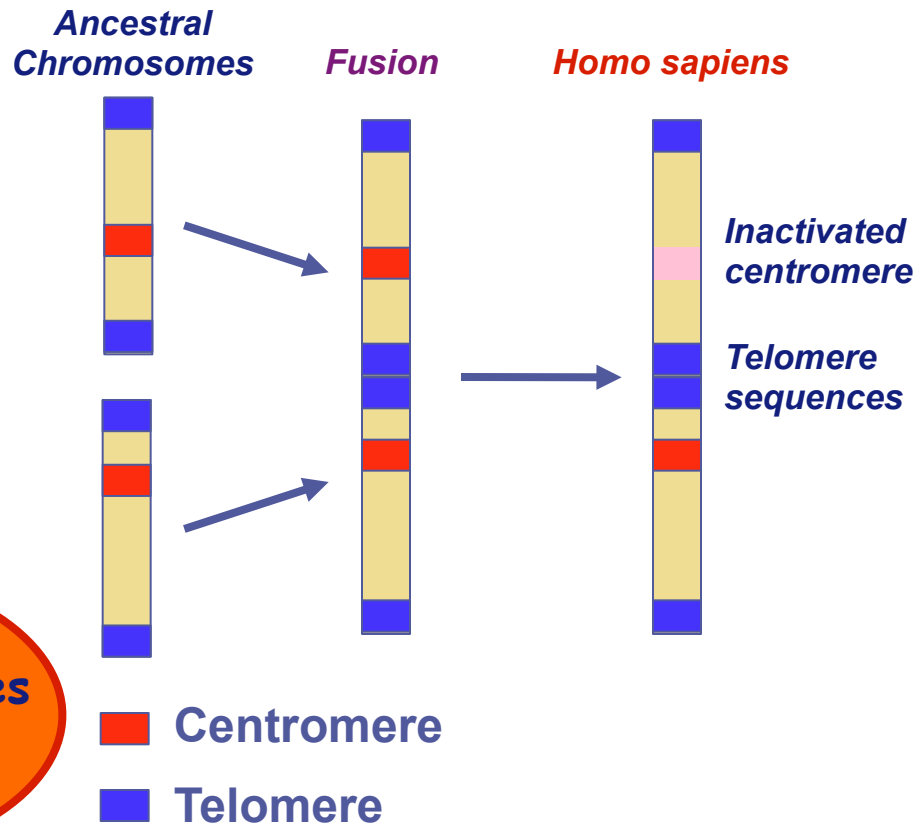
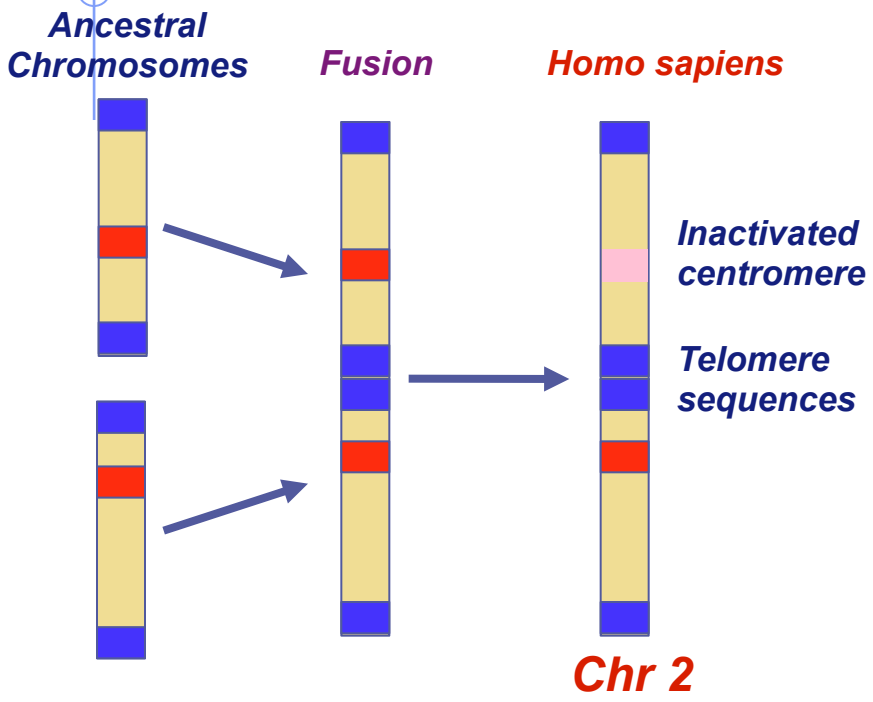


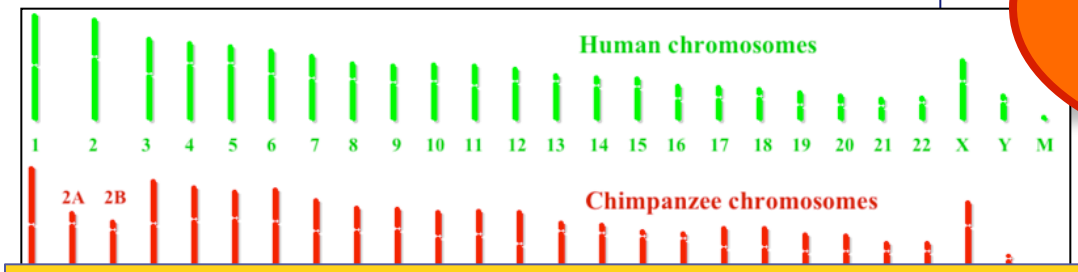


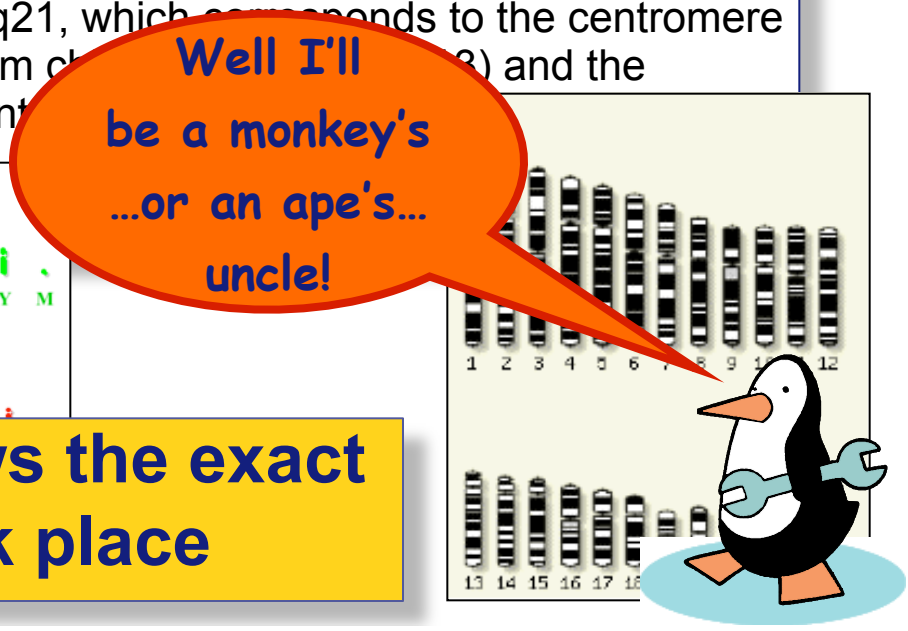
Hillier *et al* (2005) "Generation and Annotation of the DNA sequences of human chromosomes 2 and 4," Nature 434: 724 – 731.

Test of the Human Genome



"Chromosome 2 is unique to the human lineage of evolution, having emerged as a result of head-to-head fusion of two chromosomes that remained separate in other primates. The precise fusion site has been located in 2q13–2q14.1, where our analysis confirmed the presence of multiple subtelomeric duplications to chromosomes 1, 5, 8, 9, 10, 12, 19, 21 and 22. During the formation of human chromosome 2, one of the two centromeres became inactivated (2q21, which corresponds to the centromere from ch 3) and the cent





Human Chromosome #2 shows the exact point at which this fusion took place

Evolution is "so overwhelmingly established that it has become irrational to call it a theory."

-- Ernst Mayr

What Evolution Is

2001

Professor Emeritus, Evolutionary Biology

Harvard University

(1904-2005)

Don’t be a Dodo…

Ask Questions*!!*