Examples of natural selection provide evidence of evolution

The evolution of resistance to insecticides in hundreds of insect species is a classic example of natural selection in action.

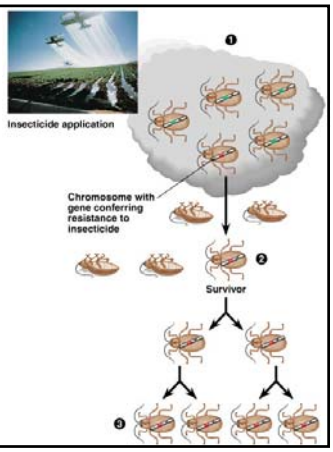
Insecticides are poisons that kill insects that are pests in crops, swamps, backyards, and homes.

The results of an application of a new insecticide are typically encouraging, killing 99% of the insects.

However, the effectiveness of the insecticide becomes less effective in subsequent applications.

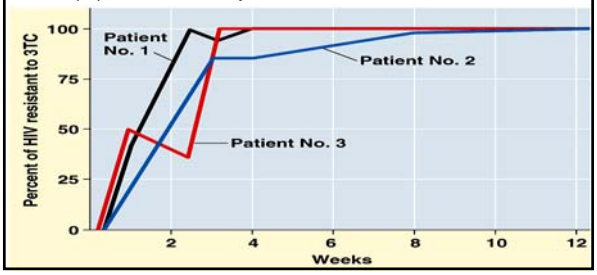
- The few survivors from the early applications of the insecticide are those insects with genes that enable them to resist the chemical attack.
- Only these resistant individuals reproduce, passing on their resistance to their offspring.
- In each generation the percentage of insecticide-resistant individuals increases.

- In general, natural selection operates not to create variation, but to edit existing variation.
- For example, resistant insects are favored and non-resistant individuals are not when insecticides are applied.
- Natural selection favors those characteristics in a variable population that fit the current, local environment.



While researchers have developed many drugs to combat HIV, drug-resistant strains evolve rapidly in the HIV population infecting each patient.

For example: patients treated with the drug 3TC, which interferes with genome replication in HIV, 3TC-resistant strains become 100% of the population of HIV in just a few weeks.



While researchers have developed many drugs to combat HIV, drug-resistant strains evolve rapidly in the HIV population infecting each patient.

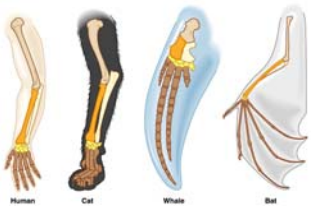
The evolution of drug resistance or pesticide resistance differ only in speed, not in basic mechanism, from other cases of natural selection.

Other evidence of evolution

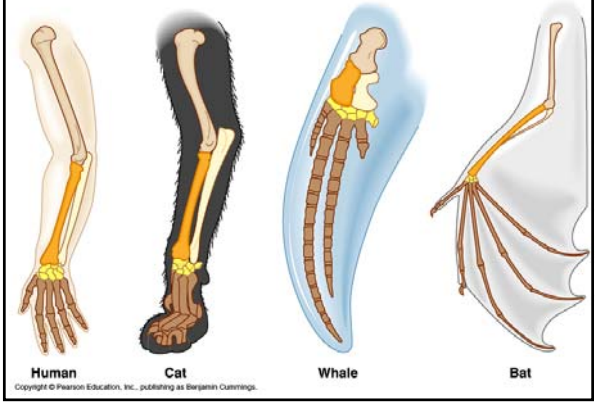
- In addition to those cases in which we can observe evolution directly, we see evidence of evolution by natural selection in the much grander changes in biological diversity documented by the fossil record.
  - Evidence that the diversity of life is a product of evolution pervades every research field of biology.
  - As biology progresses, new discoveries, including the revelations of molecular biology, continue to validate the Darwinian view of life.

- In descent with modification, new species descend from ancestral species by the accumulation of modifications as populations adapt to new environments.
  - The novel features that characterize a new species are not entirely new, but are altered versions of ancestral features.
  - Similarity in characteristics resulting from common ancestry is known as **homology**.

- Descent with modification is evident in anatomical similarities between species grouped in the same taxonomic category.
- For example, the forelimbs of human, cats, whales, and bats share the same skeletal elements, but different functions because they diverged from the ancestral tetrapod forelimb.
- They are called **homologous structures**.



Homologous structures: anatomical signs of descent with modification



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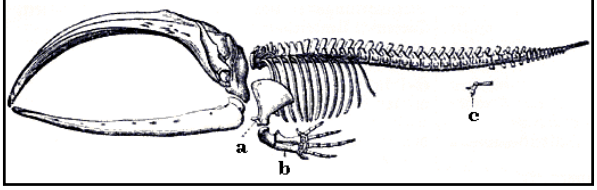
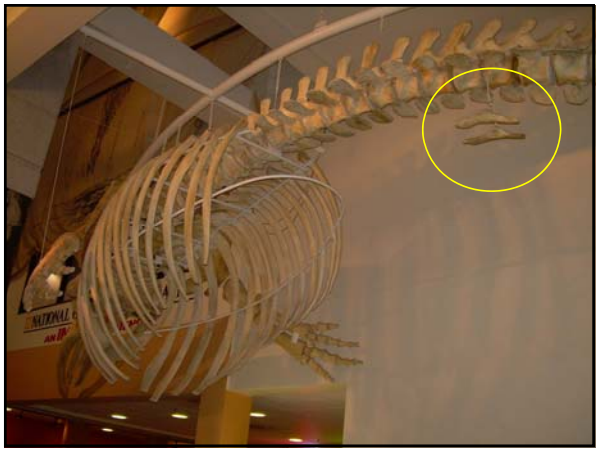
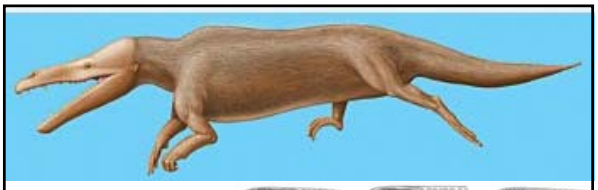
Comparative anatomy confirms that evolution is a remodeling process -- an alteration of existing structures.

For example, the back and knee problems of bipedal humans are an unsurprising outcome of adapting structures originally evolved to support four-legged mammals.

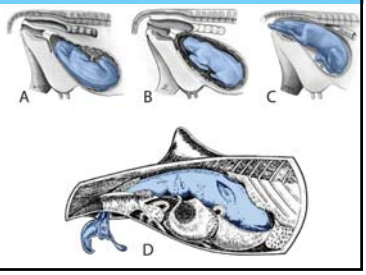
- Some of the most interesting homologous structures are **vestigial organs**, structures that have marginal, if any, importance to a current organism, but which had important functions in ancestors.
  - For example, the skeletons of some snakes and of fossil whales retain vestiges of the pelvis and leg bones of walking ancestors.







The 47.5 million-year-old fossils, discovered in Pakistan in 2004. The fetus is positioned for head-first delivery, like land mammals but unlike modern whales, indicating that these whales still gave birth on land. Another clue to the whales' lifestyle is the well-developed set of teeth in the fetus, suggesting that Maiacetus newborns were equipped to fend for themselves, rather than being helpless in early life.



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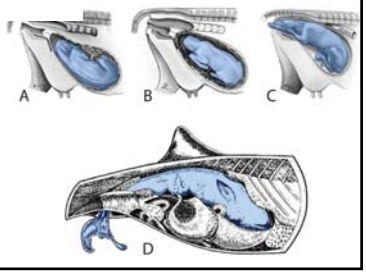
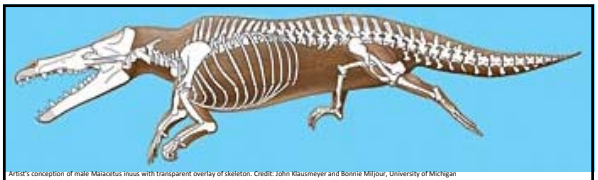
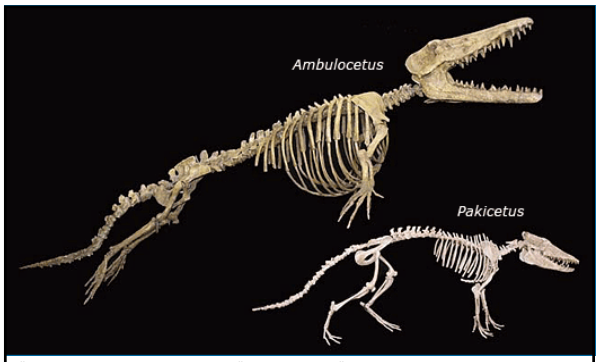




Artist's conception of male Maiacetus inuus with transparent overlay of skeleton. Credit: John Klausmeyer and Bonnie Miljour, University of Michigan

The whales' big teeth, well-suited for catching and eating fish, suggest the animals made their livings in the sea, probably coming onto land only to rest, mate and give birth.

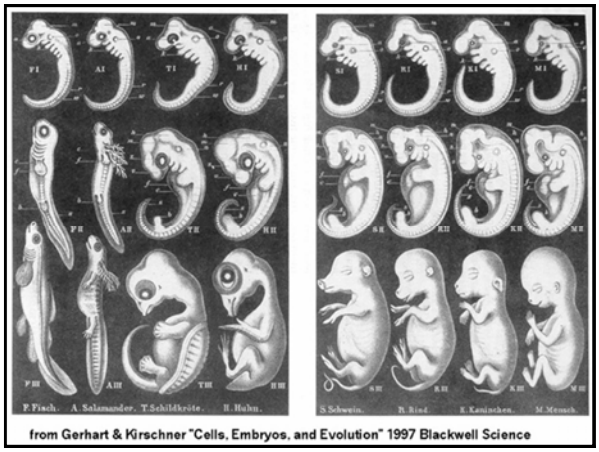
Like other primitive archaeocetes, Maiacetus had four legs modified for foot-powered swimming, and although these whales could support their weight on their flipper-like limbs, they probably couldn't travel far on land.



"They clearly were tied to the shore," Gingerich said. "They were living at the land-sea interface and going back and forth." Compared with previous fossil whale finds, Maiacetus occupies an intermediate position on the evolutionary path that whales traversed as they made the transition from full-time land dwellers to dedicated denizens of the deep.

Sometimes, homologies that are not obvious in adult organisms become evident when we look at embryonic development.

- For example, all vertebrate embryos have structures called pharyngeal pouches in their throat at some stage in their development.
- These embryonic structures develop into very different, but still homologous, adult structures, such as the gills of fish or the Eustacean tubes that connect the middle ear with the throat in mammals.



from Gerhart & Kirschner "Cells, Embryos, and Evolution" 1997 Blackwell Science

- The concept of homology also applies at the molecular level (molecular homology) and allows links between organisms that have no macroscopic anatomy in common (e.g., plants and animals).
  - For example, all species of life have the same basic genetic machinery of **RNA and DNA** and the genetic code is essentially universal.
  - Evidently, the language of the genetic code has been passed along through all the branches of the tree of life ever since the code's inception in an early life-form.

For example, the number of amino acid differences between human hemoglobin and that of other vertebrates show the same patterns of evolutionary relationships that researchers find based on other proteins or other types of data.

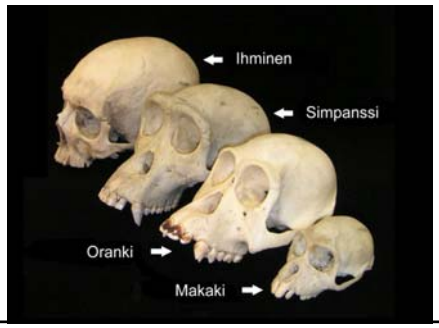
	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101
Human	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Chimpanzee	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Gorilla	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Rhesus monkey	GLN	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Horse	ALA	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Kangaroo	LYS	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU

	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
Human	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Chimpanzee	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Gorilla	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Rhesus monkey	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Horse	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	ALA	LEU	VAL	VAL	ALA	ARG
Kangaroo	ASN	PHE	LYS	LEU	LEU	GLY	ASN	ILE	ILE	VAL	ILE	CYS	LEU	ALA	GLU

- If hierarchies of homology reflect evolutionary history, then we should expect to find similar patterns whether we are comparing molecules, bones, or any other characteristics.
  - In practice, the new tools of molecular biology have generally corroborated rather than contradicted evolutionary trees based on comparative anatomy and other methods.
  - Evolutionary relationships among species are documented in their DNA and proteins -- in their genes and gene products.

- Homologies mirror the taxonomic hierarchy of the tree of life.
  - Some homologies, such as the genetic code, are shared by all life because they date to the deep ancestral past.
  - Other homologies that evolved more recently are shared only by smaller branches of the tree of life.
    - For example, only tetrapods (amphibians, reptiles, birds, and mammals) share the same five-digit limb structure.
  - This hierarchical pattern of homology is exactly what we would expect if life evolved and diversified from a common ancestor, but not what we would see if each species arose separately.

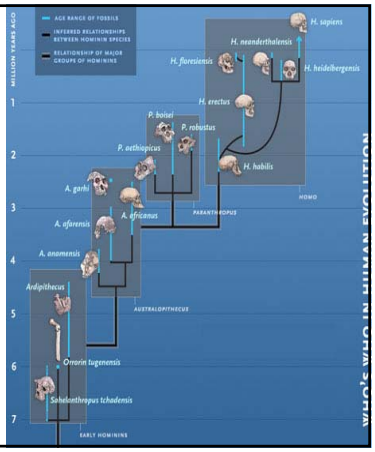
If two species have libraries of genes and proteins with sequences that match closely, the sequences have probably been copied from a common ancestor.



Despite a fragmentary fossil record augmented by rare, sometimes surprising new finds like *Homo floresiensis*, paleoanthropologists have assembled a very solid general picture of human evolution.

Scientists have traced hominins—that is, species more closely related to humans than to other apes—all the way back through the australopithecines, like the three million-year-old Lucy, to *Sahelanthropus tchadensis*, who lived over six million years ago.

The key feature that all these **hominins share is bipedalism**, which separates hominins from the primate line that eventually produced today's chimpanzees and other great apes



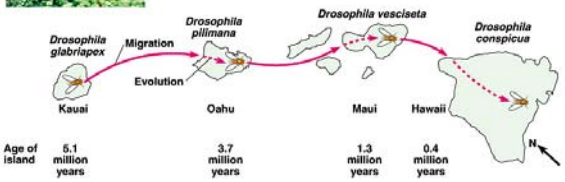
- The geographical distribution of species -- **biogeography** -- first suggested evolution to Darwin.
  - Species tend to be more closely related to other species from the same area than to other species with the same way of life, but living in different areas.

- While the sugar glider and flying squirrel have adapted to the same mode of life, they are not closely related.
- Instead, the sugar glider from Australia is more closely related to other marsupial mammals from Australia than to the flying squirrel, a placental mammal from North America.
- The resemblance between them is an example of **convergent evolution.**

Under similar environmental conditions distantly related organisms result in plants and animals that are very similar in overall appearance, this is called **convergent evolution.**

- In island chains, or archipelagos, individual islands may have different, but related, species --the first mainland invaders reached one island and then evolved into several new species as they colonized other islands in the archipelago.
  - Several well-investigated examples of this phenomenon include the diversification of finches on the Galapagos Islands and fruit flies (*Drosophila*) on the Hawaiian Archipelago.

- All of the 500 or so endemic species of *Drosophila* in the Hawaiian archipelago descended from a common ancestor that reached Kauai over 5 million years ago.



Evolution in Californian Salamanders

DAVID WAKE of the University of California, Berkeley has been studying the history of this species who began splitting apart into new species about 10 million years ago. They live in the ancient redwood forests in Northern California where we have today this form picta which is highly variable both genetically and in terms of coloration.

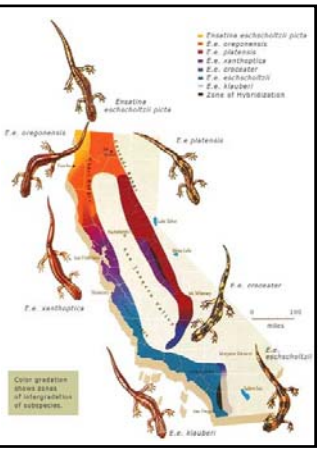
There were two migratory routes followed by animals as they moved into Southern California: one along the Sierra Nevada mountain chain where animals moved into the forest region, the other along the coastal mountains. They avoided the Great Central Valley.

As the salamanders progressed south over millions of years, the markings became more distinct.

http://www.pbs.org/wgbh/nova/evolution/evolution-action-salamanders.html

The various *Ensatina* salamanders of the Pacific coast all descended from a **common ancestral population**. As the species spread southward from Oregon and Washington, subpopulations **adapted to their local environments** on either side of the San Joaquin Valley.

From one population to the next, in a circular pattern, these salamanders are still able to interbreed successfully. However, where the circle closes -- in the black zone on the map in Southern California -- **the salamanders no longer interbreed successfully**. The variation within a single species has produced differences as large as those between **two separate species.**

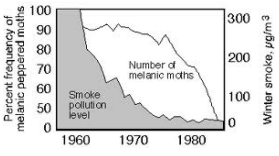


Peppered Moth

The evolution of the peppered moth over the last two hundred years has been studied in detail.

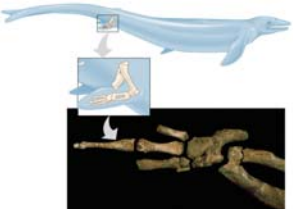
- Originally, the majority of peppered moths had light coloration, which camouflaged them on the light-colored trees.
- However, because **of pollution** during the Industrial Revolution in England, many of the trees that peppered moths rested on became blackened by soot, causing most of **the light-colored moths to die** off from predation.
- At the same time, the **dark-colored moths** flourished because of their ability to hide on the **darkened trees**.

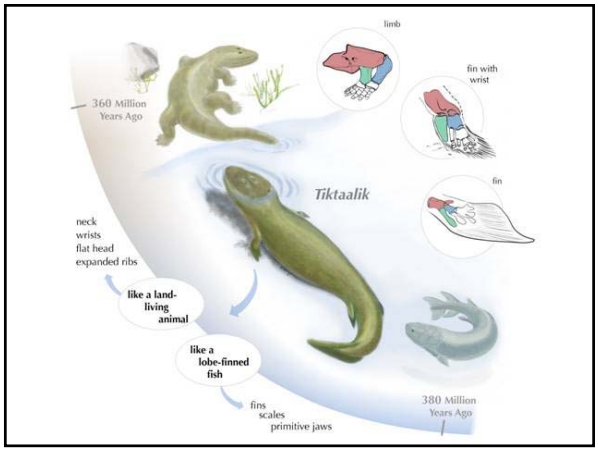
With improved environmental standards, light-colored peppered moths have again become common, but the dramatic change in the peppered moth's population has remained a subject of much interest and study, and has led to the coining of the term **industrial melanism** to refer to the genetic **darkening of species** in response to pollutants.



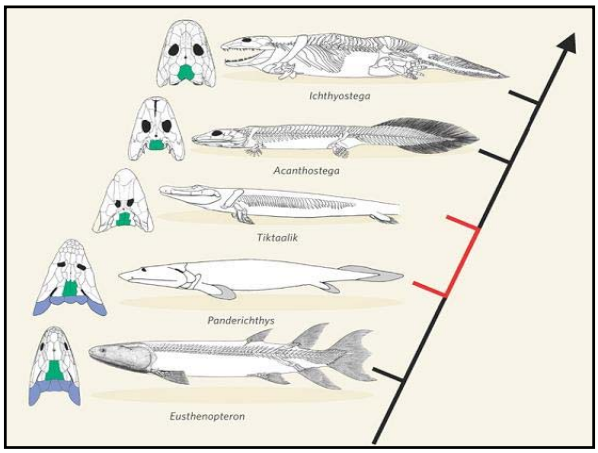
- The succession of fossil forms is compatible with what is known from other types of evidence about the major branches of descent in the tree of life.
  - For example, **fossil fishes predate all other vertebrates, with amphibians next, followed by reptiles, then mammals and birds.**
    - This is consistent with the history of vertebrate descent as revealed by many other types of evidence.
  - In contrast, **the idea that all species were individually created** at about the same time **predicts that all** vertebrate classes would make their first appearance in the fossil record **in rocks of the same age**.
    - This is **not** what paleontologists actually observe.

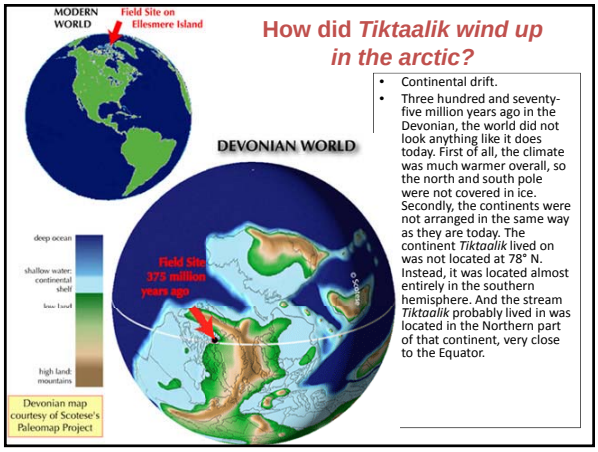
- The Darwinian view of life also predicts that evolutionary transitions should leave signs in the fossil record.
  - For example, a series of fossils documents the changes in skull shape and size that occurred as mammals evolved from reptiles.
  - Recent discoveries include fossilized whales that link these aquatic mammals to their terrestrial ancestors.





- *Tiktaalik* was found in the Canadian Arctic, at approximately 78° North latitude. *Tiktaalik* was discovered in Devonian-aged rocks of Ellesmere Island, Nunavut, Canada.
- This land is ideal for fossil hunting because unlike much of the rest of North America, there is very little vegetation due to the extreme winter temperatures, the short growing season, and the permafrost. With rock faces exposed, it's easy to spot fossils eroding out of the sediments.

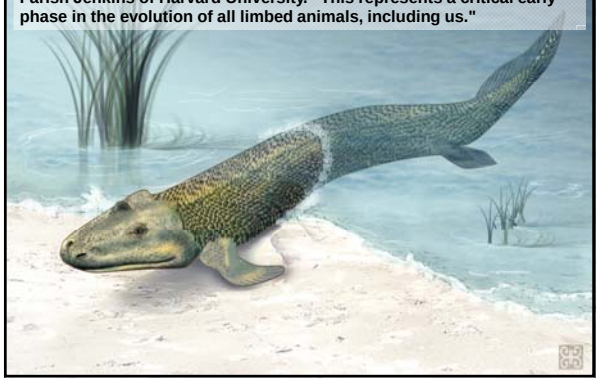


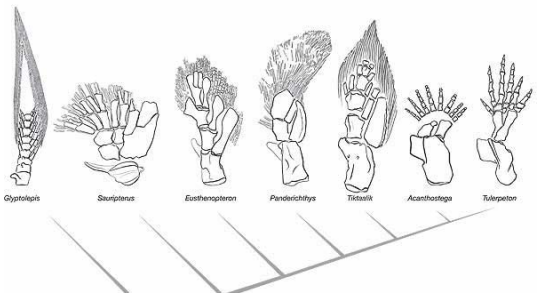


How did *Tiktaalik wind up in the arctic?*

- Continental drift.
- Three hundred and seventy-five million years ago in the Devonian, the world did not look anything like it does today. First of all, the climate was much warmer overall, so the north and south pole were not covered in ice. Secondly, the continents were not arranged in the same way as they are today. The continent *Tiktaalik* lived on was not located at 78° N. Instead, it was located almost entirely in the southern hemisphere. And the stream *Tiktaalik* probably lived in was located in the Northern part of that continent, very close to the Equator.

"The skeleton of Tiktaalik indicates that it could support its body under the force of gravity whether in very shallow water or on land," said Farish Jenkins of Harvard University. "This represents a critical early phase in the evolution of all limbed animals, including us."





Unlike other tetrapodomorph fishes *Tiktaalik* has reduced the unjointed lepidotrichia, expanded the radials to a proximal, intermediate and distal series, and established multiple transverse joints in the distal fin. The fin also retains a mosaic of features seen in basal taxa. The central axis of enlarged endochondral bones is a pattern found in basal sarcopterygians and accords with hypotheses that a primitive fin axis is homologous to autopodial bones of the tetrapod limb.

Those limbs tell us something about the evolution of limbs. *Tiktaalik* was definitely not a terrestrial animal, but had developed muscular, bony limbs and a strong pectoral girdle that had helped it prop itself up on the substrate, perhaps even holding itself partly out of the water.

The jointed digits were capable of extension and flexion, splaying out when they were pressed against the ground. That simple function, of spreading out to increase the surface area of limb contact, could be the precursor to the flexibility we now have in our hands.

What is **theoretical** about Evolution?

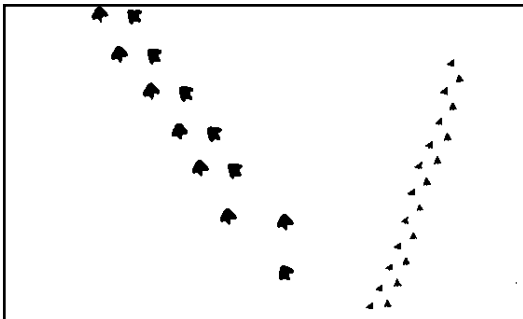
- Arguments by individuals dismissing the Darwinian view as "just a theory" suffer from two flaws.
  - First, it fails to separate Darwin's two claims: that modern species evolved from ancestral forms and that natural selection is the main mechanism for this evolution.
- **The conclusion that life has evolved is supported by an abundance of historical, fossil and genetic evidence.**
  - To biologists, Darwin's theory of evolution is natural selection -- the mechanism that Darwin proposed to explain the historical facts of evolution documented by fossils, biogeography, and other types of evidence.

- The "just a theory" arguments concerns only Darwin's second point, his theory of natural selection.
  - Here lies the second flaw, as the term *theory* in common use is closer to the concept of a "hypothesis" in science.
  - In science, a theory is more comprehensive than a hypothesis.
  - A theory, such as Newton's theory of gravitation or Darwin's theory of natural selection, accounts for many facts and attempts to explain a great variety of phenomena.

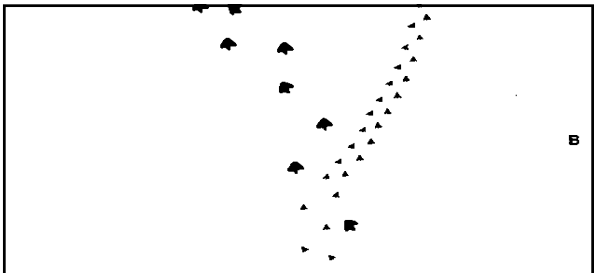
- Natural selection is widely accepted in science because its predictions have withstood thorough, continual testing by experiments and observations.
  - However, science is not static and arguments exist among evolutionary biologists concerning whether natural selection alone accounts for the history of life as observed in the fossil record.
- The study of evolution is livelier than ever, but these questions of how life evolves in no way imply that most biologists consider evolution itself to be "just a theory."

Believe or accept

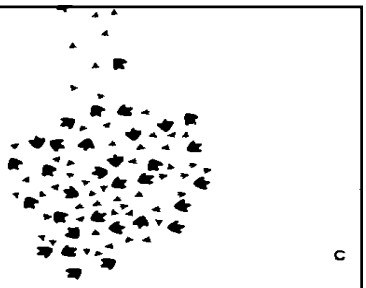
- "Do you believe in evolution?" is a question I am often asked as a biology teacher.
- The answer is, "I don't believe, I accept the fact that the Earth is very old and life has changed over billions of years because that is what the evidence tells me."
- Science is not about belief—it is about making inferences based on evidence.



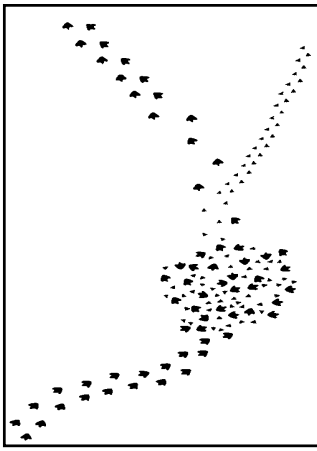
Carefully study the figure. In your notebook make an observation that is valid for this part of the puzzle. What do you think is happening? Why? Consider such factors as size, shape, orientation, etc. for each footprint as you record your observations.



Record one inference that describes in a meaningful way what you think might have happened to cause the footprints to show the pattern that they have here

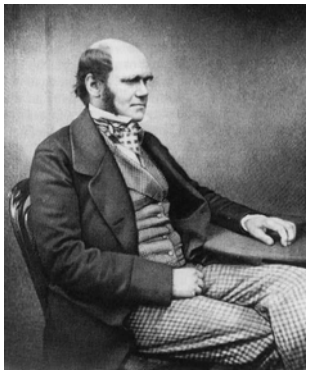


Record one inference that describes in a meaningful way what you think might have happened to cause the footprints to show the pattern that they have here



Now that you have made three observations and have viewed the entire figure, write a conclusion to this puzzle that attempts to reconstruct events that could have caused the pattern of footprints shown in the diagram.

Inferences

- When scientists study indirect evidence, such as the evidence of evolution found in fossils and living organisms, they must often make inferences, or educated guesses about the events that produced the evidence.
- Often times, scientists cannot directly test their inferences through experimentation and must rely on incomplete evidence when coming to a conclusion. The evidence of evolution contained in the fossil record is incomplete because many organisms died without leaving a trace and because scientists may not be certain when and where the fossils formed.
- As a result, many inferences about evolution cannot be proven or disproven. However the theory of evolution is the theory that is most supported by scientific evidence and reasoning.

- By attributing the diversity of life to natural causes rather than to supernatural creation, Darwin gave biology a sound, scientific basis.
- As Darwin said, “There is grandeur in this view of life.”