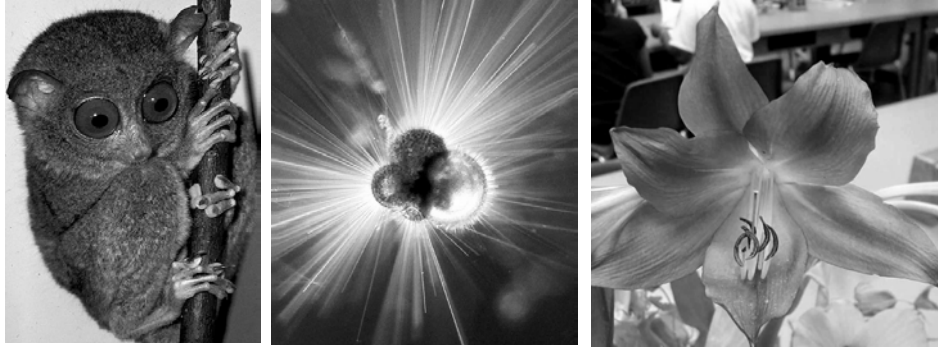


Biology & Science



Biology - the study of things that are alive; how they work, how they maintain themselves in a living state, how they survive and reproduce, how they interact with each other and their environment

1

What is Life?

Living things can be recognized through their properties

Living things have **order** that they create and they maintain their order - nonliving things decay, erode, etc. without active attempts to regain order

Living things exhibit **homeostasis** - the maintenance of their order within relatively narrow limits

Living things are **sensitive** to changes in their environment. Environmental change in temperature, pH, light, etc. results in changes in living things.

To exhibit homeostasis, living things **regulate** their body functions and properties in an appropriate way. This is also called **physiological adaptation**.

2

Physiological Adaptation -

Example - Some fish move from seawater to freshwater during different periods of their lives. When they move, they must respond to changes in the salt concentration in the water around them to keep the proper balance of salt and water in their bodies.



A fish in freshwater has 2 problems - gain of water, loss of salts

Solution: absorb salt from water at gills, make lots of urine

A fish in seawater has 2 problems - loss of water, gain of salts

Solution: secrete salt at gills, make very little urine

A fish moving from freshwater to the sea must change the way it regulates salt and water. As its physiological problems change, it shifts from one system for solving its problems to the other. They exhibit sensitivity, regulation, and homeostasis.

3

Living things **require energy**. Maintenance of order requires energy. Some living things can derive energy from sunlight, some from chemicals, others are consumers and derive their energy from other living things. Regardless of the source of energy, if living things are deprived of energy, they eventually lose their ability to maintain order and die.

Living things have a tendency to **grow** and **reproduce**. They usually have the ability to generate more life.



Living things **evolve** - they change through time and change in response to environmental change in a way that makes them better at surviving and reproducing in the new environment. This is **evolutionary adaptation**.

Because there is variety in every type of organism, and because some variants may have better abilities to survive and reproduce in different types of environments, organisms change as their environment changes. Those that are better able to survive and reproduce in the new conditions replace those that are less able.

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Evolutionary Adaptation -

2

Example - Industrial Melanism in Peppered Moths

Kettlewell worked in England in the 1950s.

He noticed that the Peppered Moth (*Biston betularia*) was light colored in unpolluted forests and dark colored in polluted forests.

He asked “**Why?**” and then proposed an explanation that involved evolutionary adaptation. He proposed that birds and other predators ate more light moths than dark moths in polluted forests, and more dark moths than light moths in unpolluted forests **because** moths that matched their background were camouflaged and less likely to be seen and eaten.



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Kettlewell tested his idea.

He raised both dark and light moths, marked them and released them in equal numbers in polluted and unpolluted forests. He then trapped moths at the edge of the forest to measure their relative survival.

In a polluted forest, Kettlewell recaptured ____ of light moths and ____ of dark moths.

In an unpolluted forest, Kettlewell recaptured ____ of light moths and ____ of dark moths.

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Kettlewell's observations, question, proposed explanation, and test is an example of the scientific method in biology. It would have shown that Kettlewell's idea was wrong if it was wrong.

Life's properties - order, homeostasis, sensitivity, regulation, growth, reproduction, evolution

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The various disciplines within biology study the properties of living things:

Physiology & Cell Biology - how living things maintain their organization

Biochemistry, Physiology, Ecology - how living things obtain energy

Genetics & Embryology - how living things reproduce and self-organize

Physiology - how living things sense and respond to environmental changes

Evolution - how living things adapt, how diversity is produced

Ecology & Behavior - how living things interact with each other and their environment

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Science - A way of knowing about the nature of reality.
a process of investigation that allows us to know about things that we can't observe directly

Steps in the Scientific Method

Observation - make an observation or set of observations about some organism or phenomenon

Question - why? or how? or what causes it?

Hypothesis - it might (could, must) be that

Prediction - if my hypothesis is incorrect (correct) then I should find ... through an experiment or comparison that

Test - an experiment or comparison that is designed to tell you if your hypothesis is wrong.

Conclusion - my results do not fit (fit) my predictions, therefore the hypothesis that I proposed is incorrect (maybe correct).

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Scientific Theory - a broad idea about the nature of reality with many supporting observations and tests -

A scientific theory explains many related facts and ties them together in a way that makes sense. Theories often bring previously unrelated facts together and allow predictions to be made about things that have not been observed yet.

Examples:

- Theory of the Atom
- Theory of Light
- Big-Bang Theory
- Cell Theory
- Germ Theory
- Theory of Evolution

Scientific theories are not guesses or speculations.

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Science depends upon **one very important assumption**: We live in a physical world, and we can understand the cause of all phenomena through physical principles. In other words, scientists assume there is a physical basis for every physical event. For a scientist physical reality is ordered by physical principles only and we can understand it through physical investigation.

In biology, we assume that cells and organisms are physical in existence and the mechanisms that control their functioning from day to day are entirely physical.

If this assumption were not true, science would be worthless. If there were unknowable causes of physical events, then no predictions could be made with certainty. The results of tests that have been made many times before might be different on any given day because of unknowable causes.

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Scientific Reasoning

_____ - using general principles to make conclusions about specific cases

_____ - using observations to derive general principles

Deduction -

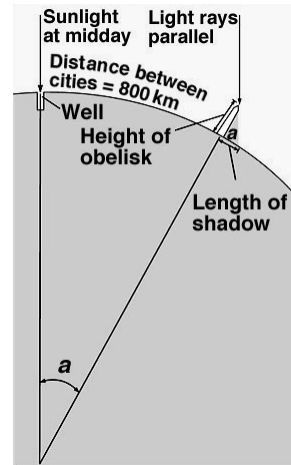
Example - Erastosthenes (200 BC) estimated the circumference of the earth

He found a way to measure the angle of sun's rays to the earth at two distant locations on the earth. That gave him angle a .

He knew the distance between the locations.

He used mathematical reasoning:

$$\text{Circumference} = (360^\circ/a^\circ) * \text{distance}$$



Induction - using observations to derive general principles

Observations -

- Organisms with disease X also have organism Y living in their tissues
- Organisms that do not have disease X do not have organism Y living in their tissues

Question - Why?

Hypothesis - Organism Y causes disease X

Prediction - if a disease free organism that lacks organism Y is infected with organism Y, it will develop disease X

Test - inoculate disease free organism with organism Y to see if disease develops

Conclusion -

if prediction is incorrect: Y does not cause disease X

if prediction is correct: Y is the probable cause of disease X

The method of inductive reasoning is also called the **Hypothetico-Deductive Method**

Use a hypothesis as if it were an already established general principle to develop a prediction that explains a general phenomenon. If the hypothesis is not supported in tests, then it is not a general principle. If the hypothesis is supported then use the hypothesis to make more predictions to test. Ultimately the hypothesis may become well established and used to make broader conclusions. (Such as: Diseases similar to disease X are caused by organisms like Y.)

Science builds by using discoveries to allow more predictions that lead to further discoveries.

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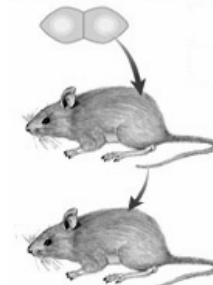
Fred Griffith in 1928 described the first known example of _____ . (p. 282)

Griffith was working with two strains of *Streptococcus pneumoniae* (a bacterium that causes pneumonia in mammals)

the “Smooth” strain “S” -
makes smooth cultures and
is virulent (deadly)



the “Rough” strain “R” -
makes rough cultures and is
nonvirulent (not deadly)



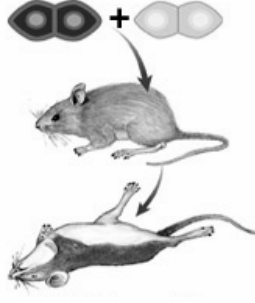
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Griffith was trying to understand the difference between the two strains and made many different observations under different conditions:

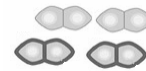
Mice inoculated with heat-killed "S"



Mice inoculated with a mixture of heat-killed "S" and live "R"



The bodies of the dead mice contained a mixture of live "R" and live "S"



Griffith hypothesized that some chemical in the killed S "transformed" the live R into S. Griffith repeated his results with cultured bacteria.

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In 1944, Avery, McCleod & McCarty used Griffith's findings to test two hypotheses about the chemical identity of the genetic material. (p 283)

Hypothesis 1: Protein (a complicated biological molecule) is the genetic material, and is responsible for transformation.

Hypothesis 2: DNA (another complicated biological molecule) is the genetic material, and is responsible for transformation.

Used two enzymes in their experiments:

protease - destroys proteins

DNase - destroys DNA

Experiments:

1. Heat-killed S + live R → live R and live S
2. Heat-killed S treated with protease + live R → live R and live S
3. Heat-killed S treated with DNase + live R → only live R

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Experiments:

1. Heat-killed S + live R → live R and live S
2. Heat-killed S treated with protease + live R → live R and live S
3. Heat-killed S treated with DNase + live R → only live R

Conclusions:

1. Protease has no effect on transformation - protein is not responsible for transformation (reject Hypothesis #1)
2. DNase stops transformation - DNA is the probable agent of transformation (provisionally accept Hypothesis #2)

Today the idea that DNA is the genetic material has been exposed to so many critical tests that it is a scientific theory (which means that it is considered a scientific fact).

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The Theory of Evolution

Originally a hypothesis conceived by Charles Darwin (1809-1882)

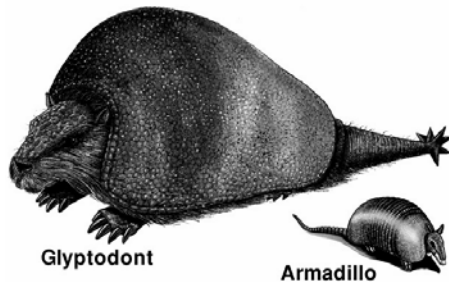
Based on observations made while the naturalist on “The Beagle.”



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Darwin's Observations

- Each continent had its own unique plants and animals. Even when they have similar climates the organisms are different. e.g. - Australia has marsupial mammals. South America has many placental mammals. Armadillos are found only in the new world. Why?
- Fossils found in an area are most similar to living forms in that area.
e.g. Glyptodont and Armadillo - What happened to Glyptodonts and where did Armadillos come from?



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- Deeper stratigraphic layers had plants and animals that were more different from living species than were shallower stratigraphic layers. Where did those ancient forms go?
- Oceanic islands had their own unique plants and animals. Why didn't all islands have the same island species?
- Plants and animals on oceanic islands were most similar to species found on the nearest continent. Why?



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- Species found in each area seemed to well suited to the environment in which they were living - if large seeds were only seeds available - seed eating birds had large beaks, if small seeds were the available food then the birds had small beaks - How did this come about?



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Darwin hypothesized that evolution had occurred. Species had changed through time. Armadillos were the descendants of Glyptodonts. Species evolved on each land mass independent of other land masses. Species evolved to be well suited for conditions in which they lived.

But how?

Darwin read widely in search of an answer. Two pieces of evidence lead him to an explanation of how evolution had occurred.

1. Selective breeding of plants and animals - produces new varieties that suit the whim of the human doing the selecting.
2. The extreme potential for animals and plants to multiply results in a “struggle for existence”

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Thomas Malthus - a social scientist - wrote “**Essay on the Principle of Population**” (1798)

Malthus noticed that human and animal populations have the potential to grow geometrically: $2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow \text{etc.}$

And, if they do, they will eventually outstrip their food supply.

However, populations commonly remain relatively stable. Why?

Because as the birth rate increases so does the death rate. Increased population growth results in increased suffering for the members of the population.

Darwin concluded that “there is a struggle for existence” and ...

“Can we doubt . . . that individuals having any advantage, however slight, over others, would have the best chance of surviving and procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favorable variations, I call Natural Selection.”

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Darwin’s Timeline:

1831-1836 - Voyage of the Beagle

1839 - conceived idea of Natural Selection

1839 - 1841 - tested idea of evolution against known facts

1842 - wrote a draft of his argument but did not publish

1843 - 1858 - worked on other things (barnacles, earthworms, plant growth, etc.)

1858 - received letter from Alfred Russell Wallace outlining Wallace’s hypothesis of evolution by natural selection

1858 - presented his and Wallace’s ideas to the Linnaean Society of London

1859 - published “**On the Origin of Species by Means of Natural Selection or The Preservation of Favoured Races in the Struggle for Life.**”

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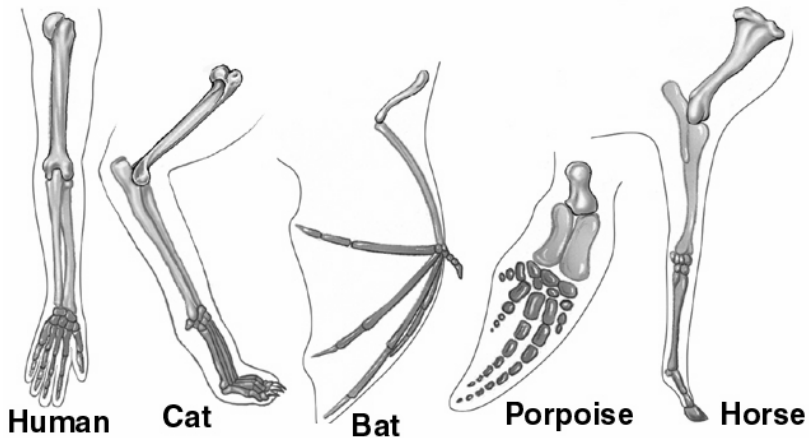
The Origin of Species presented the evidence for evolution and proposed that natural selection was the mechanism.

Darwin's evidence:

- Examined the fossil record and found progression from simpler to more complex forms and no complex forms were found in the earliest stratigraphic layers
- Found fossils in an area were similar to living forms in the same area.
- The flora and faunas of land masses with similar climates differed in proportion to their distance. Nearest land masses had the most similar forms.
- Islands often have distinctive species but they are always most similar to species on the nearest mainland.

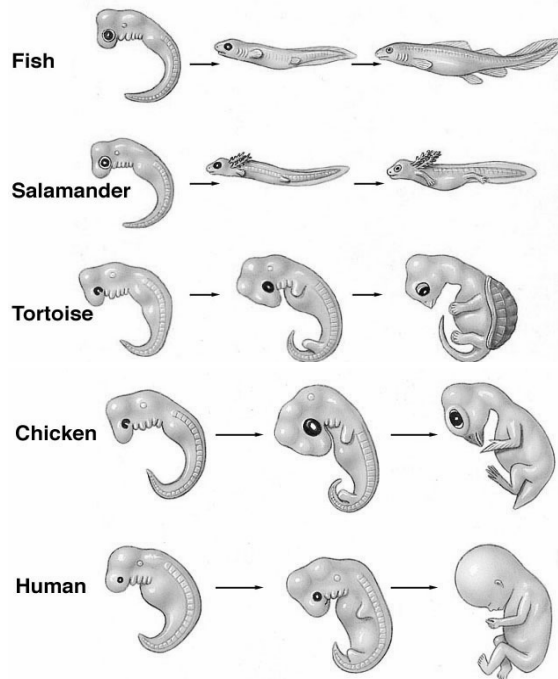
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Largely dissimilar forms retained the same underlying structure -
“ _____ ”



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Many organisms with dissimilar adults have similar embryonic starting points and similar developmental sequences.



Throughout his book, Darwin presented his attempts to find evidence against evolution and laid out the evidence that, if found, would refute his hypothesis.

“If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. ”

“If it could be proved that any part of the structure of any one species had been formed for the exclusive good of another species, it would annihilate my theory, for such could not have been produced through natural selection. ”

Evidence for Evolution has continued to grow

The fossil record is much better known today and still supports the idea that modern forms are modifications of ancestral forms. They have evolved.

Geologists and physicists have provided evidence that the Earth is much older than anyone imagined in Darwin's time, 4.6 billion years old. Time has allowed the evolution of today's diversity.

Knowledge of the mechanisms of inheritance and DNA function yield the conclusion that inheritance in every living thing is based on the same genetic principles and genetic variation allows for natural selection.

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Comparative studies of anatomy leads to the conclusion that relatively new structures, like the wings of birds, are modifications of pre-existing structures.

The field of molecular biology has only strengthened earlier conclusions about descent from common ancestors and has allowed a refinement of estimates of the genealogy of modern species.

Studies of development have strengthened evidence for a principle stated by early biologists - "Ontogeny recapitulates phylogeny" - The developmental sequence of organisms is a summary of their evolutionary relationships.

"Nothing in biology makes sense except in light of evolution." - Theodosius Dobzhansky

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