22

Descent with Modification: A Darwinian View of Life

Lecture Presentation by Nicole Tunbridge and Kathleen Fitzpatrick

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Concept 22.2: Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life

- Some doubt about the permanence of species preceded Darwin’s ideas
Darwin’s Research

- As a boy and into adulthood, Charles Darwin had a consuming interest in nature
- Darwin first studied medicine (unsuccessfully), and then theology at Cambridge University
- After graduating, he took an unpaid position as naturalist and companion to Captain Robert FitzRoy for a 5-year around the world voyage on the Beagle
The Voyage of the Beagle

- During his travels on the *Beagle*, Darwin collected specimens of South American plants and animals.
- He observed that fossils resembled living species from the same region, and living species resembled other species from nearby regions.
- He experienced an earthquake in Chile and observed the uplift of rocks.
- Darwin was influenced by Lyell’s *Principles of Geology* and thought that the earth was more than 6,000 years old
- His interest in geographic distribution of species was kindled by a stop at the Galápagos Islands west of South America
- He hypothesized that species from South America had colonized the Galápagos and speciated on the islands
Darwin’s Focus on Adaptation

- In reassessing his observations, Darwin perceived adaptation to the environment and the origin of new species as closely related processes.

- From studies made years after Darwin’s voyage, biologists have concluded that this is what happened to the Galápagos finches.
Figure 22.6

(a) Cactus-eater

(b) Insect-eater

(c) Seed-eater
In 1844, Darwin wrote an essay on **natural selection** as the mechanism of descent with modification, but did not introduce his theory publicly.

Natural selection is a process in which individuals with favorable inherited traits are more likely to survive and reproduce.

In June 1858, Darwin received a manuscript from Alfred Russel Wallace, who had developed a theory of natural selection similar to Darwin’s.

Darwin quickly finished *The Origin of Species* and published it the next year.
The Origin of Species

- Darwin explained three broad observations
  - The unity of life
  - The diversity of life
  - The match between organisms and their environment
Descent with Modification

- Darwin never used the word *evolution* in the first edition of *The Origin of Species*
- The phrase *descent with modification* summarized Darwin’s perception of the unity of life
- The phrase refers to the view that all organisms are related through descent from an ancestor that lived in the remote past
In the Darwinian view, the history of life is like a tree with branches representing life’s diversity.

Darwin reasoned that large morphological gaps between related groups could be explained by this branching process and past extinction events.
Figure 22.7

[Diagram of a tree-like structure with handwritten notes around it.]

I think...
Figure 22.8

Hyracoidea (Hyraxes)

Sirenia (Manatees and relatives)

†Moeritherium

†Barytherium

†Deinotherium

†Mammut

†Platybelodon

†Stegodon

†Mammuthus

Elephas maximus (Asia)

Loxodonta africana (Africa)

Loxodonta cyclotis (Africa)
Years ago
Millions of years ago
60
34
24
5.5
2
10
4
0
Figure 22.8b

†Platybelodon

†Stegodon

†Mammuthus

Elephas maximus (Asia)

Loxodonta africana (Africa)

Loxodonta cyclotis (Africa)

Millions of years ago

Years ago
Artificial Selection, Natural Selection, and Adaptation

- Darwin noted that humans have modified other species by selecting and breeding individuals with desired traits, a process called **artificial selection**

- Darwin drew two inferences from two observations
Figure 22.9

Selection for flowers and stems

Selection for stems

Selection for apical (tip) bud

Selection for axillary (side) buds

Selection for leaves

Brussels sprouts

Kohlrabi

Cabbage

Wild mustard

Kale

Broccoli
Observation #1: Members of a population often vary in their inherited traits
Observation #2: All species can produce more offspring than the environment can support, and many of these offspring fail to survive and reproduce.
Inference #1: Individuals whose inherited traits give them a higher probability of surviving and reproducing in a given environment tend to leave more offspring than other individuals.
Inference #2: This unequal ability of individuals to survive and reproduce will lead to the accumulation of favorable traits in the population over generations.
- Darwin was influenced by Thomas Malthus, who noted the potential for human population to increase faster than food supplies and other resources

- If some heritable traits are advantageous, these will accumulate in a population over time, and this will increase the frequency of individuals with these traits

- This process explains the match between organisms and their environment
Natural Selection: A Summary

- Individuals with certain heritable traits survive and reproduce at a higher rate than other individuals.
- Natural selection increases the match between organisms and their environment over time.
- If an environment changes over time, natural selection may result in adaptation to these new conditions and may give rise to new species.
- Note that individuals do not evolve; populations evolve over time
- Natural selection can only increase or decrease heritable traits that vary in a population
- Adaptations vary with different environments
Concept 22.3: Evolution is supported by an overwhelming amount of scientific evidence

- New discoveries continue to fill the gaps identified by Darwin in *The Origin of Species*

- There are four types of data that document the pattern of evolution
  - Direct observations
  - Homology
  - The fossil record
  - Biogeography
Direct Observations of Evolutionary Change

- Two examples provide evidence for natural selection: natural selection in response to introduced plant species, and the evolution of drug-resistant bacteria
Natural Selection in Response to Introduced Species

- Soapberry bugs use their “beak” to feed on seeds within fruits
- Feeding is most effective when beak length is closely matched to seed depth within the fruit
- In southern Florida soapberry bugs feed on the native balloon vine with larger fruit; they have longer beaks.
- In central Florida they feed on the introduced goldenrain tree with smaller fruit; they have shorter beaks.
- Correlation between fruit size and beak size has also been observed in Louisiana, Oklahoma, and Australia.
In all cases, beak size has evolved in populations that feed on introduced plants with fruits that are smaller or larger than the native fruits.

These cases are examples of evolution by natural selection.

In Florida this evolution in beak size occurred in less than 35 years.
Figure 22.13

Field Study

Soapberry bug with beak inserted in balloon vine fruit

Results

Beak length (mm)

On native species, balloon vine (southern Florida)

Average for museum specimens

On introduced species, goldenrain tree (central Florida)

Number of individuals

0 2 4 6 8 10

6 7 8 9 10 11
Field Study

Soapberry bug with beak inserted in balloon vine fruit
The Evolution of Drug-Resistant Bacteria

- The bacterium *Staphylococcus aureus* is commonly found on people.
- One strain, methicillin-resistant *S. aureus* (MRSA) is a dangerous pathogen.
- Resistance to penicillin evolved in *S. aureus* by 1945, two years after it was first widely used.
- Resistance to methicillin evolved in *S. aureus* by 1961, two years after it was first widely used.
Methicillin works by inhibiting a protein used by bacteria to produce cell walls.

MRSA bacteria use a different protein in cell wall production.

When exposed to methicillin, MRSA strains are more likely to survive and reproduce than nonresistant *S. aureus* strains.

MRSA strains are now resistant to many antibiotics.
Figure 22.14

Chromosome map of *S. aureus* clone USA300

Key to adaptations

- Orange: Methicillin resistance
- Yellow: Ability to colonize hosts
- Red: Increased disease severity
- Green: Increased gene exchange (within species) and toxin production

Annual hospital admissions with MRSA (thousands)

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Key to adaptations

- Methicillin resistance
- Ability to colonize hosts
- Increased disease severity
- Increased gene exchange (within species) and toxin production
Figure 22.14b

Annual hospital admissions with MRSA (thousands)

Year

'93  '94  '95  '96  '97  '98  '99  '00  '01  '02  '03  '04  '05

0  50  100  150  200  250  300  350  400
Natural selection does not create new traits, but edits or selects for traits already present in the population.

The current, local environment determines which traits will be selected for or selected against in any specific population.
Homology

- **Homology** is similarity resulting from common ancestry
Anatomical and Molecular Homologies

- **Homologous structures** are anatomical resemblances that represent variations on a structural theme present in a common ancestor.
Figure 22.15

Humerus
Radius
Ulna
Carpals
Metacarpals
Phalanges

Human
Cat
Whale
Bat
Comparative embryology reveals anatomical homologies not visible in adult organisms

For example, all vertebrate embryos have a post-anal tail and pharyngeal arches
Figure 22.16

- Chick embryo (LM)
  - Pharyngeal arches
  - Post-anal tail

- Human embryo
- **Vestigial structures** are remnants of features that served important functions in the organism’s ancestors.

- Examples of homologies at the molecular level are genes shared among organisms inherited from a common ancestor.
Homologies and “Tree Thinking”

- **Evolutionary trees** are hypotheses about the relationships among different groups.
- Homologies form nested patterns in evolutionary trees.
- Evolutionary trees can be made using different types of data, for example, anatomical and DNA sequence data.
Figure 22.17

Branch point

1. Digit-bearing limbs
2. Amnion
3. Homologous characteristic
4. Feathers
5. Ostriches
6. Hawks and other birds

Lungfishes
Amphibians
Mammals
Lizards and snakes
Crocodiles
Birds

Tetrapods
Amniotes
A Different Cause of Resemblance: Convergent Evolution

- **Convergent evolution** is the evolution of similar, or analogous, features in distantly related groups.
- Analogous traits arise when groups independently adapt to similar environments in similar ways.
- Convergent evolution does not provide information about ancestry.
Figure 22.18

Sugar glider

Flying squirrel

AUSTRALIA

NORTH AMERICA
The Fossil Record

- The fossil record provides evidence of the extinction of species, the origin of new groups, and changes within groups over time
Most mammals

(a) *Canis* (dog)

Cetaceans and even-toed ungulates

(b) *Pakicetus*

(c) *Sus* (pig)

(d) *Odocoileus* (deer)
Diacodexis, an early even-toed ungulate
- Fossils can document important transitions
  - For example, the transition from land to sea in the ancestors of cetaceans
Figure 22.20

Other even-toed ungulates

Hippopotamuses

†Pakicetus

†Rodhocetus

†Dorudon

Living cetaceans

Key
- Pelvis
- Tibia
- Femur
- Foot

Common ancestor of cetaceans

Millions of years ago

60 50 40 30 0
Biogeography

- **Biogeography**, the scientific study of the geographic distribution of species, provides evidence of evolution.

- Earth’s continents were formerly united in a single large continent called **Pangaea**, but have since separated by continental drift.

- An understanding of continent movement and modern distribution of species allows us to predict when and where different groups evolved.
- **Endemic** species are species that are not found anywhere else in the world.

- Islands have many endemic species that are often closely related to species on the nearest mainland or island.

- Darwin explained that species from the mainland colonized islands and gave rise to new species as they adapted to new environments.
What Is Theoretical About Darwin’s View of Life?

- In science, a theory accounts for many observations and data and attempts to explain and integrate a great variety of phenomena.

- Darwin’s theory of evolution by natural selection integrates diverse areas of biological study and stimulates many new research questions.

- Ongoing research adds to our understanding of evolution.
Guppies transplanted

Pools with pike-cichlids and guppies

Pools with killifish, but no guppies prior to transplant
Observations

- Individuals in a population vary in their heritable characteristics.
- Organisms produce more offspring than the environment can support.

Inferences

- Individuals that are well suited to their environment tend to leave more offspring than other individuals.

and

- Over time, favorable traits accumulate in the population.
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<td>4%</td>
<td>45%</td>
<td>77%</td>
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*Mosquitoes were considered resistant if they were not killed within 1 hour of receiving a dose of 4% DDT.*