The Evidence for Evolution Chapter 21



Beaks of Darwin's Finches

- Darwin collected 31 specimens from 3 islands in the Galápagos Islands
 - Darwin not an expert on birds
 - Took them back to England for identification
 - Told his collection was a closely related group of distinct species
 - All were similar except for beak characteristics
 - In all, 14 species now recognized



Woodpecker finch (Cactospiza pallida)



Large ground finch (Geospiza magnirostris)



Cactus finch (Geospiza scandens)



Warbler finch (Certhidea olivacea)



Vegetarian tree finch (*Platyspiza crassirostris*)

- Finches eat a diversity of foods
- Darwin hypothesized that different beak shapes were related to food gathering
 - Darwin wrote "... one might really fancy that ... one species has been taken and modified for different ends."

Modern research has verified Darwin's selection hypothesis

- 3 conditions of natural selection
 - Phenotypic variation must exist in the population
 - This variation must lead to differences among individuals in lifetime reproductive success
 - Phenotypic variation among individuals must be genetically transmissible to the next generation.

Peter and Rosemary Grant

- Studied medium ground finch on Daphne Major
- Found beak depth variation among members of the population
- Average beak depth changed from one year to the next in a predictable fashion
 - Droughts: birds with deeper, more powerful beaks survived better
 - Normal rains: average beak depth decreased to its original size



Peppered moths

- When the environment changes, natural selection often favors different traits in a species
- Adult Biston betularia come in a range of shades
 - Body color is a single gene
 - Black individuals have the dominant allele
 - Rare in the population until 1850s
 - From that time on, frequency increased to near 100%

- J.W. Tutt hypothesized that light-colored moths declined because of predation
- Light moths were easily seen by birds on darkened (sooty) trees
- Confirmed with separate field studies with a variety of experimental designs



© Breck P. Kent/Animals Animals/Earth Scenes

Industrial melanism

- Phenomenon in which darker individuals come to predominate over lighter ones
 - Other moths in other industrialized areas showed same trend to darken
- Pollution control resulted in bark color being lighter again
- Light-colored peppered moths now are dominant in the population

Selection against melanism.



- Agent of selection?
 - Tutt's hypothesis about the agent of selection is currently being reevaluated
 - The current reconsideration of the agent of natural selection illustrates well the way in which scientific progress is achieved
 - Hypotheses, such as Tutt's, are put forth and then tested; if rejected, new hypotheses are formulated, and the process begins anew

Artificial Selection

- Change initiated by humans
- Operates by favoring individuals with certain phenotypic traits, allowing them to reproduce and pass their genes on to the next generation
- This directional selection should result in evolutionary change

- Experimental selection
 - Drosophila melanogaster (fruit fly)
 - Selected fruit flies with many bristles on abdomen
 - At the start, average number of bristles was 9.5
 - Chose only those with most bristles to reproduce
 - 86 generations later, average number of bristles had quadrupled to nearly 40



Data from G. Dayton and A. Roberson, Journal of Genetics, Vol. 55, p. 154, 1957.

- Domestication may lead to unintentional selection for some traits
 - Attempt to domesticate silver foxes
 - Chose most docile animals only to breed
 - Within 40 years, had many of the same behavioral and physical traits as domestic dogs
 - Are traits for behavior linked to other traits?
 - Pleiotropy or linkage at work



© Courtesy of Lyudmilla N Siberian Dept. of h

Permission required for reproduction or display.



t,Institute of Cytology & Genetics, ssian Academy of Sciences



- Agricultural selection
 - Differences have resulted from generations of human selection for desirable traits, such as greater milk production and larger corn ear size

Can selection produce major evolutionary changes?

- Most scientists think that natural selection is the process responsible for the evolutionary changes documented in the fossil record
- Some critics of evolution accept that selection can lead to changes within a species, but not the substantial changes documented in the fossil record
- This argument does not fully appreciate the extent of change produced by artificial selection
 - Dog breeds would be species if found as fossils

19

- Domestication
 - Human-imposed selection has produced a variety of cats, dogs, pigeons, and others
 - Breeds may have been developed for specific purposes
 - Dachshunds for badger pursuit



Fossil Evidence of Evolution

- Fossils are the preserved remains of once-living organisms
 - The age of fossils can be estimated
- Rock fossils are created when three events occur
 - Organism buried in sediment
 - Calcium in bone or other hard tissue mineralizes
 - Surrounding sediment hardens to form rock
- Process of fossilization is rare event

Evolutionary transitions

- Given the low likelihood of fossil preservation and recovery, it is not surprising that there are gaps in the fossil record
- Intermediate forms have been found
- Oldest known bird fossil is the Archaeopteryx
 - Clearly intermediate between bird and dinosaur
 - Possesses some ancestral traits and some traits of present day birds



© Kevin Schafer/Peter Arnold Inc.

Archaeopteryx

- Recent discoveries
 - Four-legged aquatic mammal
 - Important link in the evolution of whales and dolphins from land-dwelling, hoofed ancestors
 - Fossil snake with legs
 - *Tiktaalik*: a species that bridged the gap between fish and the first amphibian
 - Oysters: small curved shells to large flat shells



Ambulocetus natans probably walked on land (as do modern sea lions) and swam by flexing its backbone and paddling with its hind limbs (as do modern otters).

Pakicetus attocki lived on land, but its skull differed from that of its ancestors and exhibited many characteristics seen in whales today.

- Horse evolution
 - Modern Equidae are all large, long-legged, fastrunning animals adapted to life on open grasslands
 - First horse was small with short legs
 - Wooded habitats
 - Path to modern horse involved
 - Changes in size
 - Toe reduction
 - Changes in tooth size and shape
 - Adaptations to climate change
 - Grasslands became more widespread
 - Rates of evolution have varied widely

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



- Modern horse diversity is relatively limited
- At peak of horse diversity there were 13 genera in North America alone

Anatomical Evidence for Evolution

- Homologous structures
 - Structures with different appearances and functions that all derived from the same body part in a common ancestor
 - The bones in the forelimb of mammals are homologous structures
 - Different functions, same ancestor structure



- Early embryonic development
 - Strongest anatomical evidence supporting evolution comes from comparisons of how organisms develop
 - Embryos of different types of vertebrates, for example, often are similar early on, but become more different as they develop
 - Early vertebrate embryos possess pharyngeal pouches that develop into
 - In humans: glands and ducts
 - In fish: gill slits



- Imperfections some organisms do not appear perfectly adapted
- Workable but imperfect solutions
- Most animals with long necks have many vertebrae for flexibility
 - Geese: 25
 - Plesiosaurs: 76
 - Mammals: 7
 - The giraffe has 7 vertebrae, very large in size, to make up for the length of the neck



- Eyes of vertebrates
 - Photoreceptors face backward
 - Nerve fibers slightly obscure light and create a blind spot
 - Mollusks' eyes are more optimally designed with no obstruction or blind spot 33



- Vestigial structures
 - Have no apparent function, but resemble structures their ancestors possessed
 - Human ear wiggling muscles
 - Hip bones in boa constrictors
 - Evolutionary relicts

Biogeography

- Study of the geographic distribution of species
- Reveals that different geographical areas sometimes exhibit groups of plants and animals of strikingly similar appearance, even though the organisms may be only distantly related
- Natural selection appears to have favored parallel evolutionary adaptations in similar environments

Convergent evolution

- Similar forms having evolved in different, isolated areas because of similar selective pressures in similar environments
- Marsupial and placental mammals
 - Only marsupials found in Australia
 - Australian marsupials resemble placental mammals on other continents





- Convergence among fast-moving marine predators
- Hydrodynamics of moving through water require a streamlined body shape to minimize friction
- Sharks, tuna, icthyosaurs, and dolphins

Biogeographical studies

- Darwin noted on his voyage that
 - Islands are often missing plants and animals common on continents
 - Can live there if introduced
 - Species present on islands often diverged from continental relatives
 - Occupy niches used by other species on continents
 - Island species usually are more closely related to species on nearby continents

- Darwin concluded:
 - Many islands have never been connected to the mainland
 - Species arrive on islands by dispersing across the water
 - Dispersal from nearby areas is more likely than distant sources
 - Species that can fly, float or swim are more likely to inhabit islands
 - Colonizers often evolve into many species

Darwin's critics

- Nearly universally accepted by biologists
- Source of controversy for some in the general public
- 7 principle objections
 - 1. Evolution is not solidly demonstrated
 - Just a theory like the theory of gravity
 - 2. There are no fossil intermediates
 - Many intermediates have been found since Darwin's time

- 3. The intelligent design argument
 - Too complex for a random process
 - Natural selection is not random but it is not directed
- 4. Evolution violates the Second Law of Thermodynamics
 - Things become more disorganized
 - Earth is not a closed system and energy is constantly added from the Sun
- 5. Proteins are too improbable
 - Probability of hemoglobin as random event = $(1/20)^{141}$
 - Can't argue backwards what are the odds of students having the birthdates they do in class

- 6. Natural selection does not imply evolution
 - No scientist has evolved a fish into a frog
 - Artificial selection has produced differences more distinctive than those between wild species
- 7. The irreducible complexity argument
 - Intricate machinery of cell cannot be explained by evolution from simpler stages
 - Natural selection can act on a complex system because at every stage of its evolution, the system functions