Populations: Evolution and Natural Selection
EVPP 110 Lecture
Instructor: Dr. Largen  Fall 2003

Historical Background

✓ Ideas about evolution
  – originated before Darwin
    • mid-350s BC
    • 1500s
    • 1600s
    • 1700s
    • 1800s

✓ mid-350s BC
  – Aristotle
    • noted evidence of natural similarities and relationships among organisms
    • lead him to arrange all organisms he knew into a “Scale of Nature”
      – extended from most simple to most complex
    • visualized living organisms as being
      – imperfect but “moving toward a more perfect state”

✓ 1500s
  – fossils
    • term coined in early 1500s
      – to describe remains of ancient organisms
    • of familiar living organisms
    • in unexpected contexts
      – marine invertebrate fossils imbedded in rocks on high mountains

✓ 1500s
  – fossils
• some unlike any known form
• Leonardo da Vinci
  – first interpret these finds
  » as remains of animals that had existed in past but had become extinct

Historical Background

1600s
  – emergence of modern scientific
1700s
  – exploration of continents
  – discovery of new species
  – emergence of idea
    • natural world of living organisms must be guided by natural laws
    • as physical world was governed by physical laws

Historical Background

1800s
  1809
    • Jean Baptiste de Lamarck, French naturalist, published *Philosophie Zoologique*
    • Charles Darwin born

Historical Background

1800s
  Jean Baptiste de Lamarck, French naturalist
  • published *Philosophie Zoologique*, in 1809
  • expressed most accepted view of evolution of that time
    – all living organisms were endowed with vital force that drove them to change
      toward greater complexity over time
    – organisms could pass traits acquired during their lifetimes on to their offspring
      » example, ancestral giraffe

Historical Background

Darwin’s life and experiences led to development of his theory of evolution
  – born in 1809
  – son physician
  – sent to University of Edinburgh to study medicine at age 15
    • found himself unsuited for medicine
  – transferred to Cambridge University to study theology and received his degree

Historical Background

Darwin’s life and experiences
  – 1831 (at age 22)
    • embarked on 5-year round-the-world voyage
    – as naturalist on *H.M.S. Beagle*
– profoundly influenced his thinking
  • during voyage
    – read extensively about geology
    – collected 1000s of specimens
      » plants, animals, fossils, including marine snail fossils in Andes
    – observed unique adaptations of organisms

15 Historical Background
✓ Darwin’s life and experiences
  – 1836
    • returned to England at end of voyage
    • his reading and experiences had led him to
      – seriously doubt current thinking of the time
        » Earth and living organisms were relatively new and unchangeable
    • had come to believe that Earth was very old and constantly changing

16 Historical Background
✓ early 1840s
  – Darwin had composed an essay describing major features of his theory
    • delayed publishing it because
      – he knew it would cause a social furor
✓ mid-1850s
  – British naturalist Alfred Wallace, who had been doing field work in Indonesia,
    • conceived a theory identical to Darwin’s

17 Figure 22.x5 Alfred Wallace

18 Historical Background
✓ in 1858
  – Wallace’s work and excerpts from Darwin’s work were jointly presented to scientific community

19 Historical Background
✓ in 1859
  – Darwin’s text On the Origin of Species by Means of Natural Selection, was published
    • didn’t use term “evolution” at first
      – referred instead to “descent with modification”
      – perceived a unity among species
        » all organisms related through descent from unknown organisms that lived in past

20 Figure 22.0 Title page from The Origin of Species

21 Historical Background
✓ in 1859
  – On the Origin of Species by Means of Natural Selection
    • maintained that
      – as descendants spread into various habitats over millions of years
        » they accumulated adaptations that accommodated them to diverse ways of life
Historical Background

- Darwin’s phrase for evolution “descent with modification” captured the idea that
  - an ancestral species could diversify into many descendant species
    - by accumulation of different adaptations to various environments

Evidence of evolution

- fossil record
  - provides some of strongest evidence of evolution
  - an ordered array in which fossils appear within layers, or strata, of sedimentary rock
    - each strata can bear a unique set of fossils representing a local sample of organisms that lived when the sediment was deposited
    - younger strata are on top of older strata
      - position of fossils in strata reveals their relative age

- biogeography
  - geographical distribution of species
  - first suggested to Darwin that organisms evolve from common ancestors
    - environment of Galapagos islands resembled that of tropical islands from distant parts of world
      - animals of Galapagos more closely resembled species of mainland South America

- comparative anatomy
  - comparison of body structures in different species
  - anatomical similarities among many species give sign of common descent
    - same skeletal elements make up forelimbs of humans, cats, whales & bats
    - since forelimbs of these animals function differently
      - would expect their designs would be different, unless
        - they all descended from a common ancestor with same basic limb structure

Evidence of evolution

- comparative embryology
  - molecular biology
✓ Comparative anatomy
  – homologous structures
    • features that have different functions but are structurally similar because of common ancestry

30 Figure 22.17  A transitional fossil linking past and present

32 Evidence of evolution
  ✓ Comparative embryology
    – study of structures that appear during development of different organisms
    – closely related organisms often have similar stages in their embryonic development
      • one sign that vertebrates evolved from a common ancestor
        – all of them have an embryonic stage in which structures called gill pouches appear on sides of throat
          » at that stage, embryos of fishes, frogs, snakes, birds, apes look more alike than different

33 Evidence of evolution
  ✓ Molecular biology
    – study of molecular basis of genes and gene expression
    – universality of genetic code is strong evidence that all life is related
    – related individuals have greater similarity in their DNA than do unrelated individuals of same species
    – two closely related species have a greater proportion of their DNA in common than more distantly related species

34 Table 22.1  Molecular Data and the Evolutionary Relationships of Vertebrates

36 Darwin’s Theory
  ✓ In The Origin of Species
    – Darwin focused on how organisms become adapted to their environments
    – his theory arose from several key observations
      • all species tend to produce more offspring than environment can support
      • individuals of a population vary in their traits
      • organisms’ variations can be inherited by their offspring

37 Darwin’s Theory
  ✓ all species tend to produce excessive numbers of offspring (overproduction)
    – production of more individuals than an environment can support
    – leads to a struggle for existence
      • natural resources are limited
      • only a percentage of offspring in each generation survive and reproduce
        – rest are starved, eaten, frozen, diseased, unmated, unable to reproduce for some other reason

38 Darwin’s Theory
  ✓ Individuals of a population vary extensively in their characteristics
– individuals whose characteristics make them best suited (adapted) to their environment are most likely to survive
  • most likely to reproduce
    – leave more offspring than less “fit” (adapted) individuals

39 🌐 **Darwin’s Theory**
✓ Many of varying traits of individuals in a population can be passed from one generation to the next (heritable variations)
– individuals whose traits make them best suited to an environment are more likely to survive and reproduce and
  • traits that made them well adapted to their environment are likely to be inherited by their offspring

40 🌐 **Natural selection**
✓ natural selection
  – proposed by Darwin as basic mechanism of evolution
  – essence of which is differential, or unequal, success in reproduction
    • not all individuals have equal success in reproduction

41 🌐 **Natural selection**
✓ natural selection
  – higher reproductive success
    • occurs in individuals that are well adapted to their environment
      – these individuals will reproduce and pass on their traits
        » their traits will become more heavily represented in the next generation than will the traits of poorly adapted individuals

42 🌐 **Natural selection**
✓ natural selection
  – lower reproductive success
    • occurs in individuals that are poorly adapted to their environment
      – these individuals will reproduce less
        » their traits will become more less and less common in subsequent generations

43 🌐 **Natural selection**
✓ natural selection
  – individuals that are well adapted to their environment can be said to be most fit for that environment, or the “fittest”
    • hence phrase “survival of the fittest”
  – natural selection leads to, in subsequent generations,
    • favored traits (well adapted) will be represented more and more
    • unfavored traits (poorly adapted) will be represented less and less

44 🌐 **Natural selection**
✓ natural selection
  – unequal ability of individuals to survive and reproduce leads to
    • gradual change in characteristics of a population of organisms
      – over generations
        » favored characteristics accumulate
        » unfavored characteristics disappear
Natural selection

- **artificial selection** provided Darwin with evidence for his ideas on natural selection
- **definition**
  - selective breeding of domesticated plants & animals
  - by selecting individuals with desired traits as breeding stock, humans were playing role of environment and bringing about differential reproduction

Natural selection

- **artificial selection** examples
  - **plants**
    - broccoli, cauliflower, cabbages, brussel sprouts, kale and kohlrabi are all varieties of a single species of wild mustard that were produced by artificial selection
  - **animals**
    - hundreds of varieties of domestic dog, a single species called *Canis familiaris*, are result of 1000s of years of artificial selection
    - many species of canines resulted from 1000s to millions of years of natural selection

- **Darwin reasoned**
  - if artificial selection could bring about so much change in a relatively short period of time
  - then natural selection over vast spans of time would result in gradual accumulation of heritable changes that would result in evolution of new species
  - as in five species of canines thought to have evolved from a single ancestral canine

Natural selection

- **natural selection in action**
  - many examples have been documented
  - peppered moth
    - exists in two forms
      - light colored with splotches of darker pigment (where it gets its name)
      - uniformly dark variety

Natural selection

- **natural selection in action**
  - peppered moth
    - feed at night, rest during the day, on trees & rocks encrusted with lichens
      - light variety is well-camouflaged against lichens, protected from predators
      - dark variety is conspicuous, therefore not protected from predators

Natural selection

- **natural selection in action**
  - peppered moth
• Great Britain, prior to Industrial Revolution
  – dark variety of moth was rare
    » not camouflaged against lichens
    » became prey for birds before they could reproduce and pass onto next generation their genes for dark coloration

54 ☐ Natural selection
  ✔ natural selection in action
  – peppered moth
    • late 1800s, pollution from Industrial Revolution killed large numbers of lichens, exposing darker tree bark or rock
    – dark variety of moth became increasingly more abundant
      » now was camouflaged against dark surface and lighter variety was not
    • by early 1900s, in some industrial areas, populations consisted almost entirely of dark variety

55 ☐ Natural selection
  ✔ Population
  – group of individuals of same species living in same place at same time
    – is smallest unit that can evolve
      • in moth example, it was population, not individual moths, that evolved

  – population is smallest unit that can evolve

56 ☐ Natural selection
  ✔ Population
  – evolution can be measured as
    • a change in prevalence of certain heritable traits in a population over a succession of generations
    – Darwin
      • understood
        – it is populations that evolve
      • did not understand
        – genetic basis of population change

57 ☐ Natural selection
  ✔ Darwin could not explain
  – cause of variation among individuals making up a population
  – perpetuation of parents’ traits in their offspring
  ✔ Due to knowledge that came after Darwin, it is now understood that
    – mutations in genes may produce new traits
    – heritable traits are carried by genes on chromosomes

58 ☐ Natural selection
  ✔ modern synthesis
  – current version of theory of evolution that includes genetics
  – was developed in early 1940s
  – focuses on populations as units of evolution
  – includes most of Darwin’s ideas
– melds population genetics with theory of natural selection
– requires an understanding of relationship between populations and species

59 🌐 Natural selection
✓ sexual species (biological species)
– group of populations whose individuals have potential to interbreed & produce fertile offspring

60 🌐 Microevolution
✓ Studying evolution at population level
– focuses on
  • gene pool
    – total collection of genes in a population at any one time
    – reservoir from which members of next generation will derive their genes
    – can be studied by observing changes in relative frequencies of alleles over time

61 🌐 Microevolution
✓ For most genes, there are 2 or more alleles (varieties)
✓ a population at a given time can be described by relative frequencies of a particular set of alleles
✓ over time, relative frequencies of particular alleles in population can change as result of natural selection
  – leads to microevolution
    • change in gene pool
      – as in moth example

62 🌐 Microevolution
✓ frequency of each allele in gene pool will remain constant unless acted on by other agents
– population to which this applies is said to be in Hardy-Weinberg equilibrium

63 🌐 Microevolution
✓ Hardy-Weinberg equilibrium
  – suggests that something other than sexual reproduction is required to alter a gene pool
    • by changing allele frequencies from one generation to next
✓ One way to determine what factors can change a gene pool is
  – identify conditions necessary to maintain genetic equilibrium

64 🌐 Figure 23.3a The Hardy-Weinberg theorem
65 🌐 Figure 23.3b The Hardy-Weinberg theorem

66 🌐 Microevolution
✓ Hardy-Weinberg equilibrium
  – following 5 conditions must be met
    • population is very large
    • population is isolated
      – no movement into or out of population
    • gene mutations do not alter gene pool
    • mating is random
• all individuals are equal in reproductive success
  – natural selection does not occur

67 Microevolution
✓ five conditions necessary for Hardy-Weinberg equilibrium
  – rarely occur in nature
  • equilibrium breaks down
  • allele frequencies in natural populations change constantly

68 Microevolution
✓ Causes of microevolution
  – basically reverse of 5 necessary conditions for Hardy-Weinberg equilibrium
✓ 5 causes of microevolution
  – genetic drift
  – gene flow
  – mutation
  – nonrandom mating
  – natural selection

69 Microevolution
✓ Genetic drift
  – change in gene pool of a small population due to chance
  – in small population, chance event can have a disproportionately large effect
  • altering gene pool in next generation
    – iguana example, assume a small population (3 WW, 2 Ww and 5 ww)
      » an earthquake kills 3 iguana
      » 3 dead iguanas were all WW
      » frequency of W allele in next generation would be reduced

70 Microevolution
✓ Genetic drift
  – two subtypes
  • bottleneck effect
  • founder effect

71 Microevolution
✓ Genetic drift, subtypes
  • bottleneck effect
  • results from event that drastically reduces population size
  • event kills large numbers of individuals unselectively
    – produces small surviving population that is not likely to have same genetic makeup as original population
    » certain alleles will be present at higher frequencies, other alleles will be present at lower frequencies

72

73 Microevolution
✓ Genetic drift, subtypes
  • founder effect
• results from random change in a gene pool that occurs in a small colony
• colonization of a new location by a single pregnant individual or a small # of individuals
  – gene pool of subsequent generations will be derived from just these few individuals
• thought to have been important in evolution of many species in Galapagos Islands

74 📊 Figure 23.4 Genetic drift

75 📊 **Microevolution**

✓ **Gene flow**
  – gain or loss of alleles from a population by movement of individuals or gametes
  – occurs when
    • fertile individuals move into or out of a population
    • gametes are transferred from one population to another
  – minimizes genetic differences between populations

76 📊 **Microevolution**

✓ **Gene flow**
  – reduced by reproductive isolation
    • which increases genetic differences between populations
  – increased by
    • migration
    • wars

77 📊 **Microevolution**

✓ **Mutation**
  – random change in an organism’s DNA that creates a new allele
  – rare event for any given gene
    • occur ~ once per gene locus per $10^5$ to $10^6$ gametes
  – little effect on large population in a single generation
  – over time, vital to evolution because
    • ultimate source of genetic variation
      – serves as raw material for evolution

78 📊 **Microevolution**

✓ **Nonrandom mating**
  – selection of a mate other than by chance
    • random mating (chance) would require
      – every male (female) in population have an equal chance of mating with every
        female (male) in population
      – is rare in nature
      – nonrandom mating is the norm in most populations
        • for example, in humans, short males tend to marry short females

79 📊 **Microevolution**

✓ **Natural selection**
  – fifth agent of microevolution
  – differential success in reproduction
  – most likely to result in adaptive changes in a gene pool
Microevolution
✓ Some genetic variation
  – seems to have a trivial impact on reproductive success
    • therefore may not be subject to natural selection

Microevolution
✓ neutral variation hypothesis
  – proposes that species have some alleles that confer no selective advantage or disadvantage
    • frequencies of these alleles may increase or decrease as a result of chance genetic drift
      – but natural selection will not affect them
    • human fingerprints are probably an example of neutral variation

Microevolution
✓ Evolutionary fitness
  – contribution an individual makes to gene pool of next generation relative to contribution made by other individuals
  – fittest individuals in an evolutionary context are those that pass on the greatest number of genes to the next generation

Microevolution
✓ Individuals with a high degree of fitness
  – those whose phenotypic traits enable them to reproduce and contribute genes to more offspring than other individuals
✓ Favored genotypes
  – those whose positive phenotypic effects outweigh any harmful effects they may have on reproductive success of organism
✓ By culling less fit individuals, natural selection also culls unfavored genotypes

Microevolution
✓ natural selection can alter phenotypic variations in an idealized population
  – three main ways
    • stabilizing selection
    • directional selection
    • diversifying selection

Microevolution
✓ Stabilizing selection
  – favors intermediate variants
  – typically occurs in relatively stable environments
    • where conditions tend to reduce phenotypic variation
    – probably prevails most of time in most populations

Microevolution
✓ Directional selection
– shifts overall makeup of population by acting against individuals at one of phenotypic extremes
– most common
  • during periods of environmental change
  • when members of a species migrate to new habitat with different environmental conditions

Microevolution
  ✓ Diversifying selection
  – typically occurs when environmental conditions are varied in a way that favors individuals at
    • both extremes of a phenotypic range
    • rather than intermediate individuals

Microevolution
  ✓ Natural selection can produce resistant populations of pests and parasites
  – new pesticide, antibiotic, drug is fairly effective killing all but a few individuals in target population when first used
  • few survivors live and reproduce because, by chance, they have genes that protect them (provide resistance)
    – they pass these protective traits on to their offspring
    » eventually, most of population consists of resistant individuals

The End