1

Populations: Evolution and Natural Selection

EVPP 110 Lecture

Instructor: Dr. Largen Fall 2003

2

- ✓Historical background
- ✓Evidence of evolution
- ✓Darwin's theory
- ✓Natural selection
- ✓Microevolution

3 Historical Background

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

4 Historical Background

- ✓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"

5 Historical Background

- ✓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

6 Historical Background

- ✓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

7 ☐ 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

8 ☐ Historical Background

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

9 ☐ 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

10  Figure 22.x4 Jean Baptiste Lamarck

11 ☐ 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

12  Figure 22.18 Charles Darwin in 1859, the year *The Origin of Species* was published

13 ☐ 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

14

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

22 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

23 Figure 22.1 The historical context of Darwin's life and ideas

24 Evidence of evolution

✓Evidence of evolution

– fossil record

– biogeography

– comparative anatomy

– comparative embryology

– molecular biology

25 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

26 Evidence of evolution

✓**fossil record**

– shows that organisms appeared in a historical sequence

– oldest known fossils

• prokaryotes dating from ~ 3.5 BYA

– younger layers of rock reveal evolution of various groups of eukaryotes

• including successive appearance of various classes of vertebrates

– fishlike, then amphibians, then reptiles, then mammals and birds

27 Evidence of evolution

✓ **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

28 Evidence of evolution

✓**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

29 Evidence of evolution

✓**Comparative anatomy**

– **homologous structures**

• features that have different functions but are structurally similar because of common ancestry

30

31 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

35

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 <u>differential, or unequal, success in reproduction</u>
  - 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 <u>most fit</u> 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

45 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

46 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

47

48 Figure 22.11b Artificial selection: diverse vegetables derived from wild mustard

49 Figure 22.11a Artificial selection: cattle breeders of ancient Africa

50 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 hertitable changes that would result in evolution of new species
    - as in five species of canines thought to have evolved from a single ancestral canine

51 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

52 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

53 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

80 ☐ **Microevolution**

✓ Some genetic variation
- – seems to have a trivial impact on reproductive success
  - • therefore may not be subject to natural selection

81 ☐ **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

82 ☐ **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

83 ☐ **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

84 ☐ **Microevolution**

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

85 ☐

86 ☐ **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

87 ☐

88 ☐ **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

89

90 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

91

92 Figure 23.12 Modes of selection

93 Microevolution

✓ Natural selection can produced **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

94 Figure 22.12 Evolution of insecticide resistance in insect populations

95

96 The End