Chapter 13 How Populations Evolve

PowerPoint Lectures for

***Biology: Concepts & Connections*, Sixth Edition**

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Lecture by Joan Sharp

Introduction: *Clown, Fool, or Simply Well Adapted?*

- Living organisms are adapted to their environment

Introduction: *Clown, Fool, or Simply Well Adapted?*

- What is an **adaptation**?
  - Behavioral adaptations
  - Structural adaptations
  - Biochemical adaptations
  - Physiological adaptations

DARWIN'S THEORY OF EVOLUTION

13.1 A sea voyage helped Darwin frame his theory of evolution

- The primary mechanism of evolutionary change producing adaptation of organisms to their environment is **natural selection**, the differential survival and reproduction of individuals within a population

13.1 A sea voyage helped Darwin frame his theory of evolution

- The Greek philosopher Aristotle viewed species as perfect and unchanging
- In the century prior to Darwin, the study of **fossils** suggested that species had changed over time

13.1 A sea voyage helped Darwin frame his theory of evolution

- Jean Baptiste Lamarck suggested that life on Earth evolves
- His proposed mechanisms:
  - Use and disuse
  - Inheritance of acquired characteristics

PLAY Video: Blue-footed Boobies Courtship Ritual

PLAY Video: Albatross Courtship Ritual

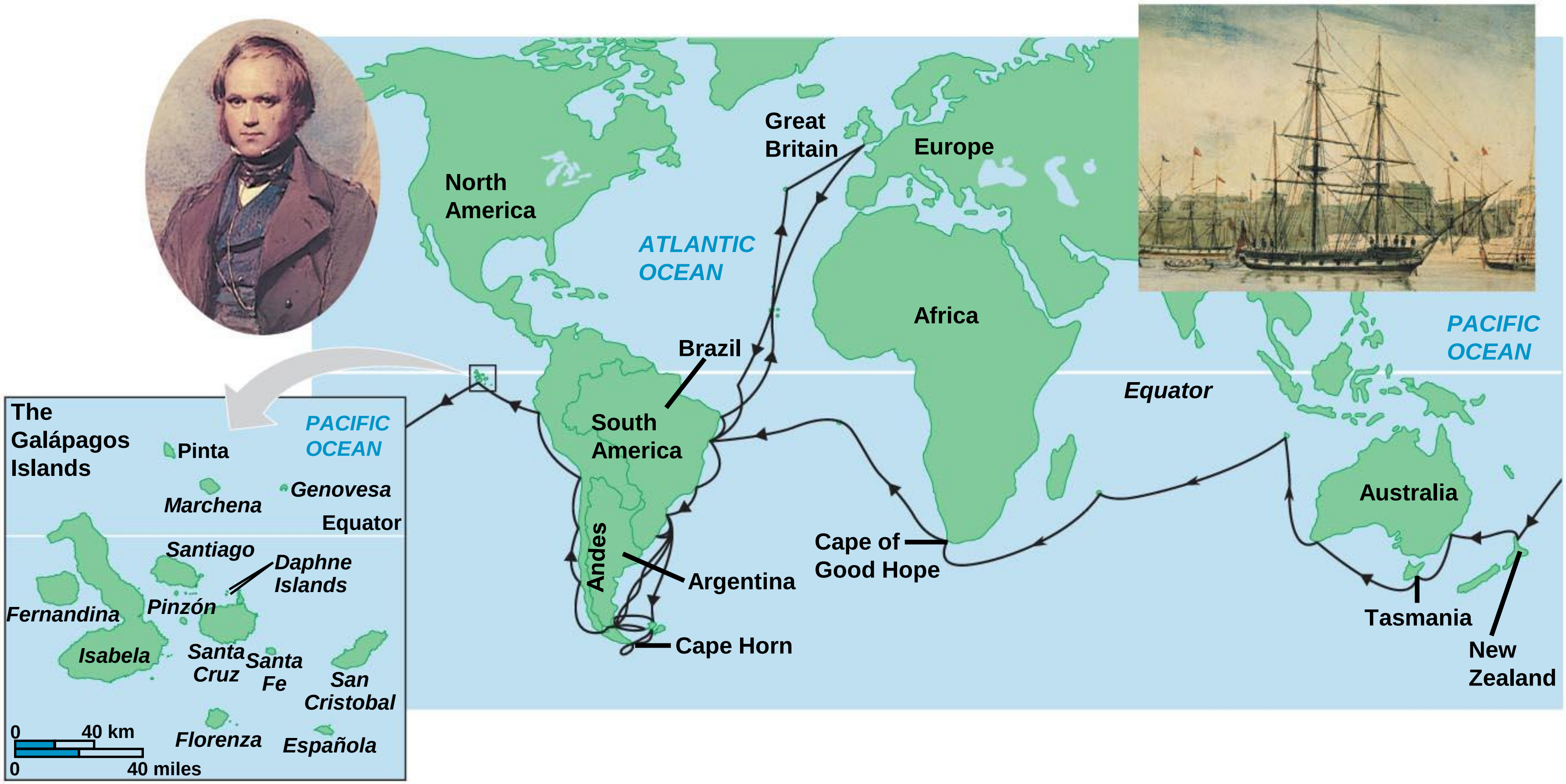
PLAY Video: Galápagos Sea Lion

PLAY Video: Galápagos Island Overview

PLAY Video: Galápagos Tortoise

PLAY Video: Galápagos Marine Iguana

PLAY Video: Soaring Hawk



North America
ATLANTIC OCEAN
Great Britain
Europe
Africa
Brazil
South America
Andes
Argentina
Cape Horn
Cape of Good Hope
Equator
PACIFIC OCEAN
Australia
Tasmania
New Zealand
The Galápagos Islands
PACIFIC OCEAN
Pinta
Marchena
Genovesa
Equator
Santiago
Daphne Islands
Fernandina
Pinzón
Isabela
Santa Cruz
Santa Fe
San Cristobal
Florenza
Española
0 40 km
0 40 miles


Great
Britain
Europe
North
America
ATLANTIC
OCEAN
Africa
PACIFIC
OCEAN
Brazil
Equator
South
America
Australia
Andes
Cape of
Good Hope
Argentina
Cape Horn
Tasmania
New
Zealand


The Galápagos Islands
PACIFIC OCEAN
Pinta
Genovesa
Marchena
Equator
Santiago
Daphne Islands
Fernandina
Pinzón
Isabela
Santa Cruz
Santa Fe
San Cristobal
0
40 km
0
40 miles
Florenza
Española

13.1 A sea voyage helped Darwin frame his theory of evolution

- Darwin was influenced by Lyell's *Principles of Geology*
- He came to realize that the Earth was very old and that, over time, present day species have arisen from ancestral species by natural processes

13.1 A sea voyage helped Darwin frame his theory of evolution

- In 1859, Darwin published *On the Origin of Species by Means of Natural Selection*, presenting a strong, logical explanation of *descent with modification,* evolution by the mechanism of natural selection

13.2 Darwin proposed natural selection as the mechanism of evolution

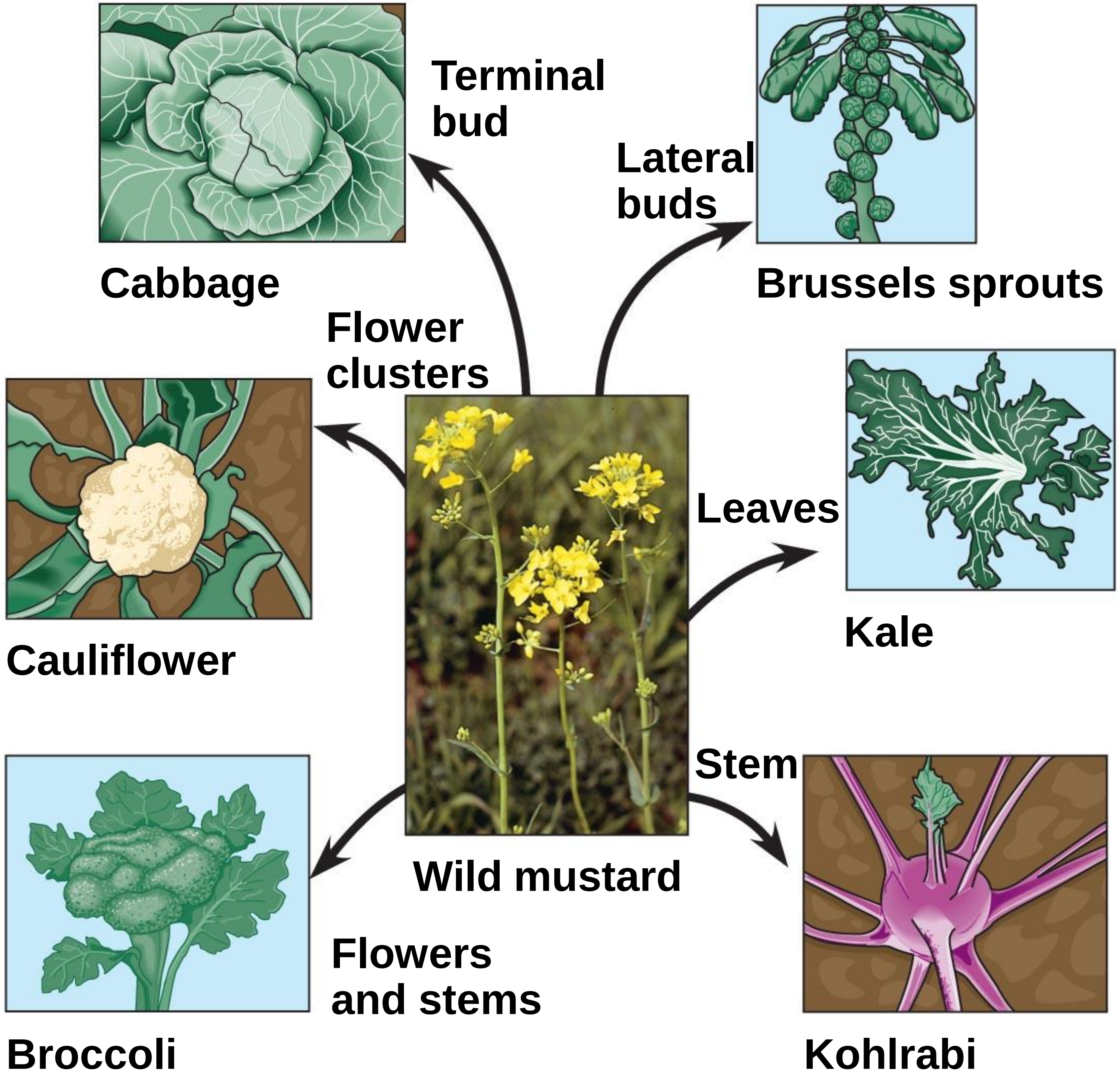
- Darwin observed that
  - Organisms produce more offspring than the environment can support
  - Organisms vary in many traits

13.2 Darwin proposed natural selection as the mechanism of evolution

- Darwin reasoned that traits that increase their chance of surviving and reproducing in their environment tend to leave more offspring than others
- As a result, favorable traits accumulate in a population over generations

13.2 Darwin proposed natural selection as the mechanism of evolution

- Darwin found convincing evidence for his ideas in the results of artificial selection, the selective breeding of domesticated plants and animals


Terminal
bud
Lateral
buds
Cabbage
Brussels sprouts
Flower
clusters
Leaves
Kale
Cauliflower
Stem
Wild mustard
Flowers
and stems
Broccoli
Kohlrabi

13.2 Darwin proposed natural selection as the mechanism of evolution

- **Note these important points**
  - Individuals do not evolve: populations evolve
  - Natural selection can amplify or diminish only heritable traits; acquired characteristics cannot be passed on to offspring
  - Evolution is not goal directed and does not lead to perfection; favorable traits vary as environments change

13.2 Darwin proposed natural selection as the mechanism of evolution

- Will natural selection act on variation in hair style in a human population?

13.2 Darwin proposed natural selection as the mechanism of evolution

- Will natural selection act on tongue rolling in a human population?

  (**Note**: Tongue rolling is an inherited trait, caused by a dominant allele)

13.2 Darwin proposed natural selection as the mechanism of evolution

- Will natural selection act on eye number in a human population?

13.3 Scientists can observe natural selection in action

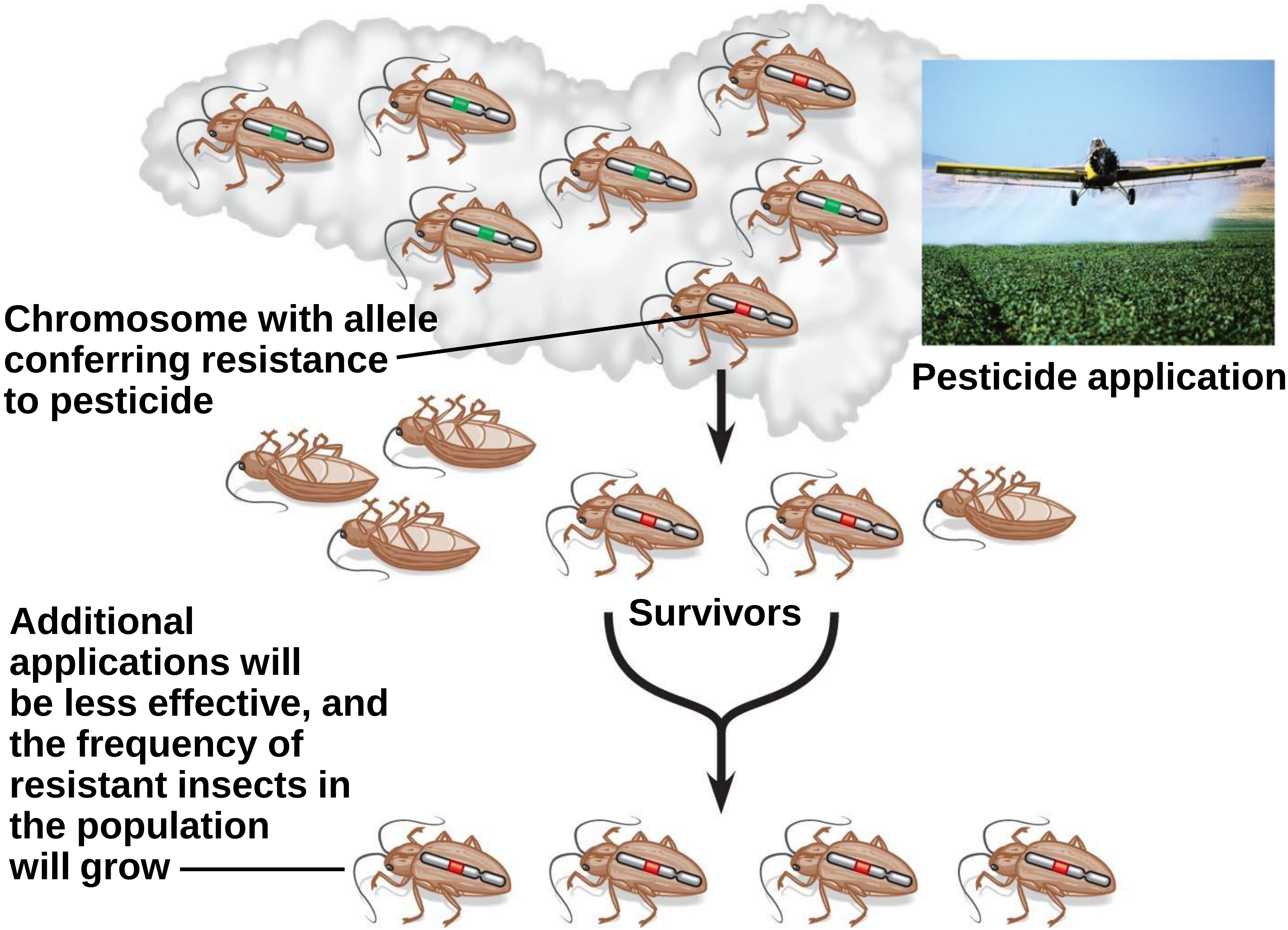
- Rosemary and Peter Grant have worked on Darwin's finches in the Galápagos for over 20 years
  - In wet years, small seeds are more abundant and small beaks are favored
  - In dry years, large strong beaks are favored because large seeds remain

PLAY Video: Seahorse Camouflage


A leaf mantid in Costa Rica

13.3 Scientists can observe natural selection in action

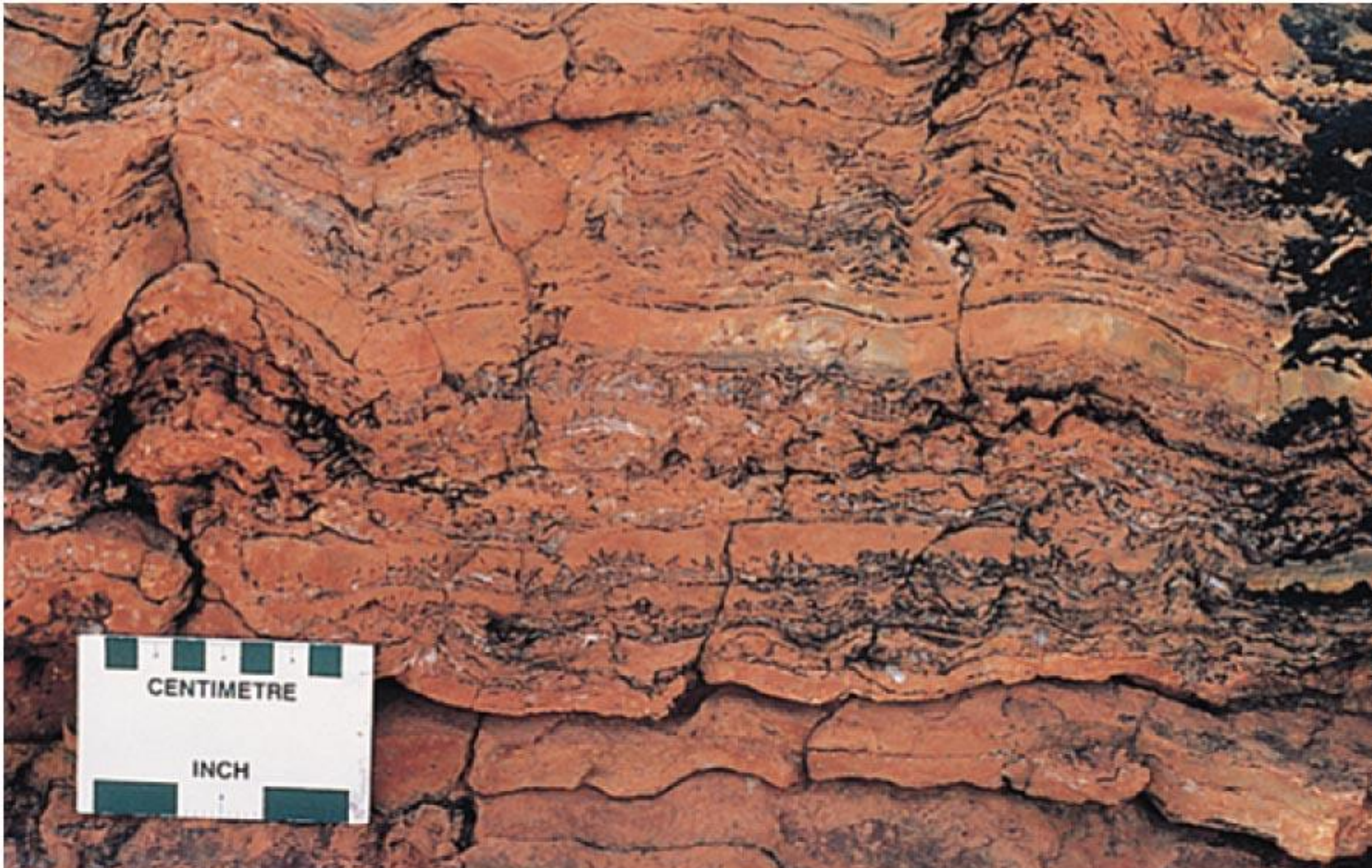
- Development of pesticide resistance in insects
  - Initial use of pesticides favors those few insects that have genes for pesticide resistance
  - With continued use of pesticides, resistant insects flourish and vulnerable insects die
  - Proportion of resistant insects increases over time


Chromosome with allele conferring resistance to pesticide
Pesticide application
Survivors
Additional applications will be less effective, and the frequency of resistant insects in the population will grow

13.4 The study of fossils provides strong evidence for evolution

- The fossil record shows that organisms have evolved in a historical sequence
  - The oldest known fossils are prokaryote cells
  - The oldest eukaryotic fossils are a billion years younger
  - Multicellular fossils are even more recent

PLAY Video: Grand Canyon


CENTIMETRE
INCH

2.5 cm

Dickinsonia costata

D Fossilized organic matter of a leaf

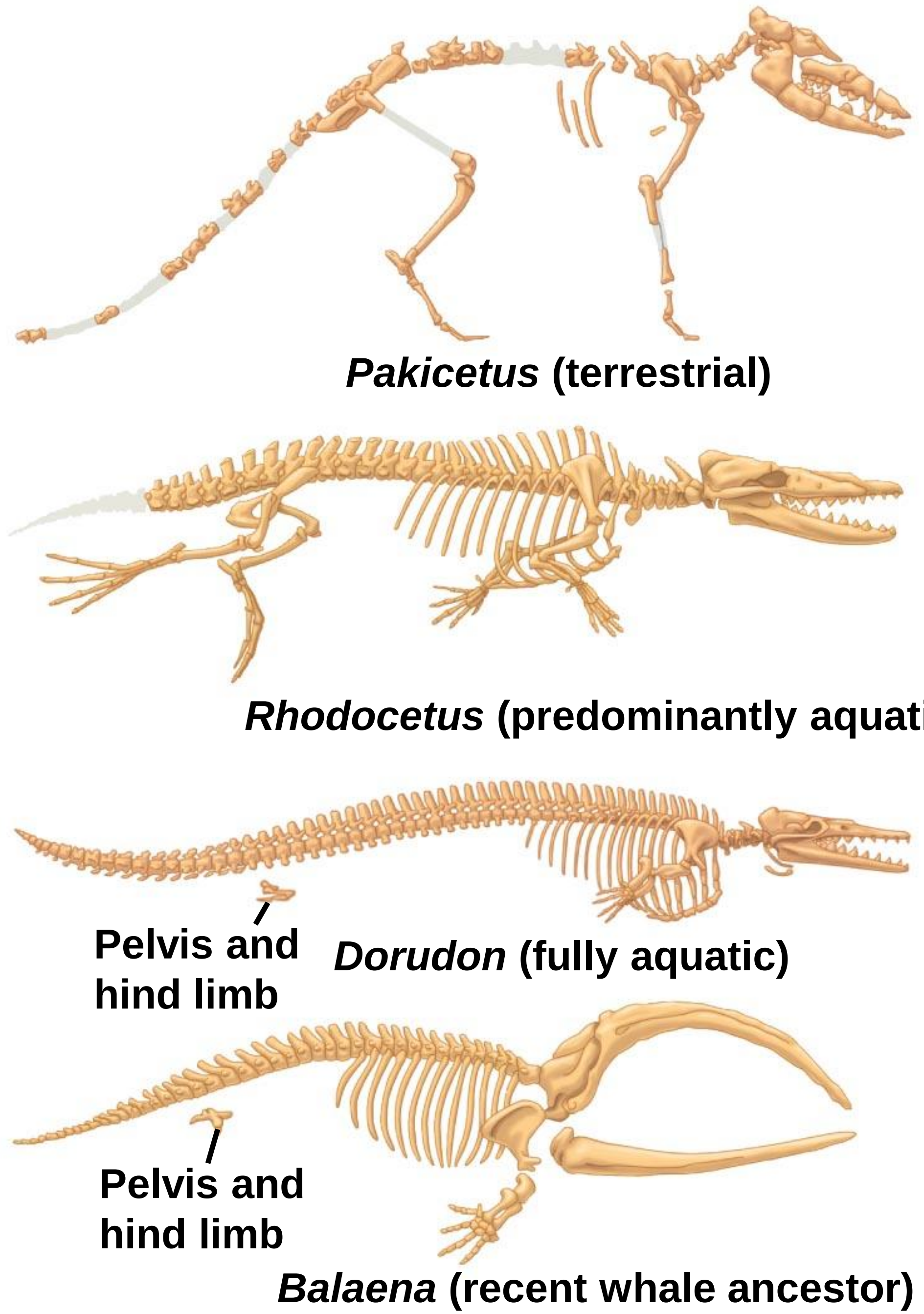
B Ammonite casts

A **Skull of *Homo erectus***

F “Ice Man”

13.4 The study of fossils provides strong evidence for evolution

- Many fossils link early extinct species with species living today
  - A series of fossils documents the evolution of whales from a group of land mammals

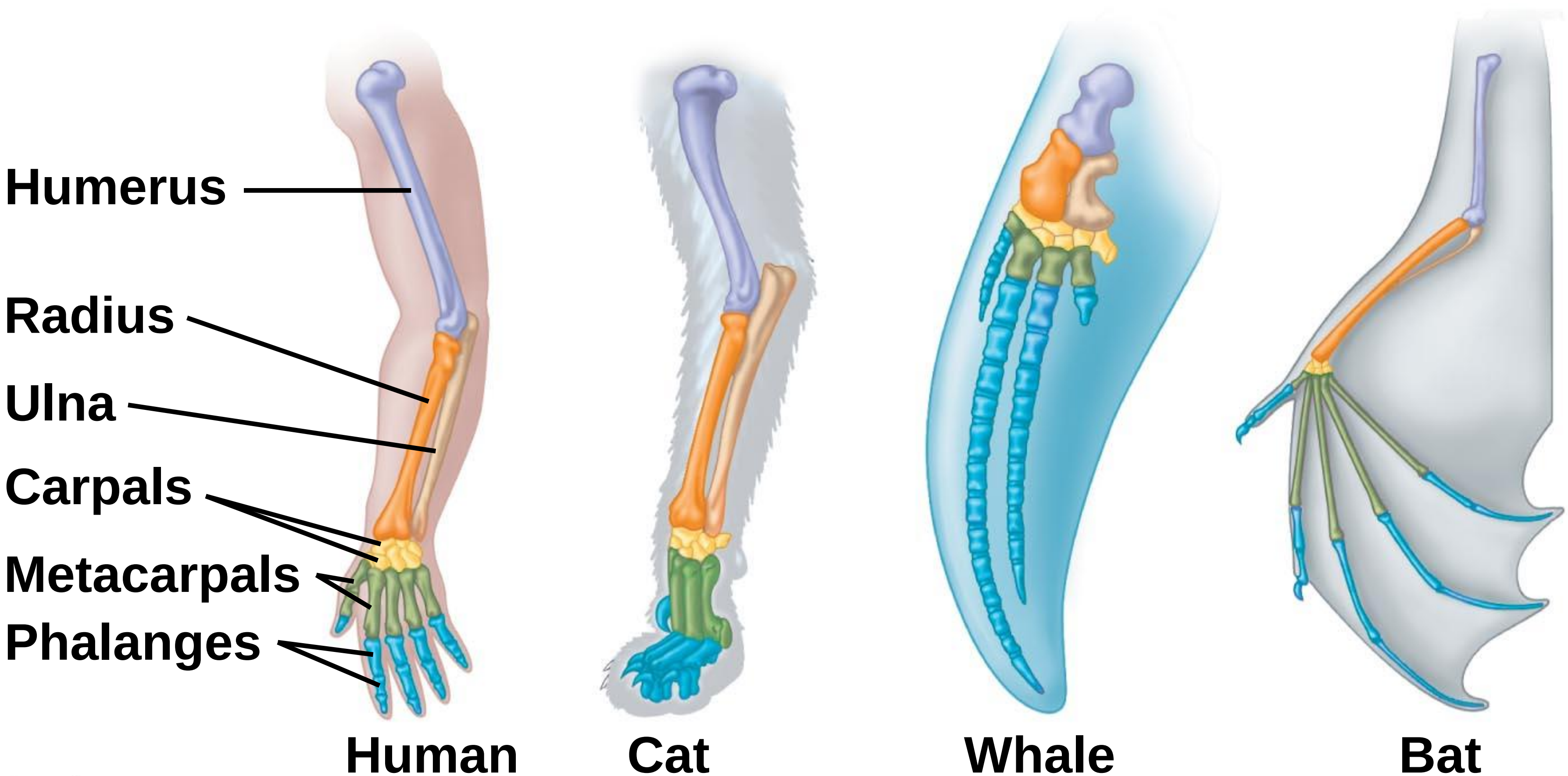

Pakicetus (terrestrial)
Rhodocetus (predominantly aquatic)
Pelvis and hind limb
Dorudon (fully aquatic)
Pelvis and hind limb
Balaena (recent whale ancestor)

13.5 A mass of other evidence reinforces the evolutionary view of life

- **Biogeography**, the geographic distribution of species, suggested to Darwin that organisms evolve from common ancestors
  - Darwin noted that animals on islands resemble species on nearby mainland more closely than they resemble animals on similar islands close to other continents

13.5 A mass of other evidence reinforces the evolutionary view of life

- **Comparative anatomy** is the comparison of body structures in different species
- **Homology** is the similarity in characteristics that result from common ancestry
  - Vertebrate forelimbs


Humerus
Radius
Ulna
Carpals
Metacarpals
Phalanges
Human
Cat
Whale
Bat

13.5 A mass of other evidence reinforces the evolutionary view of life

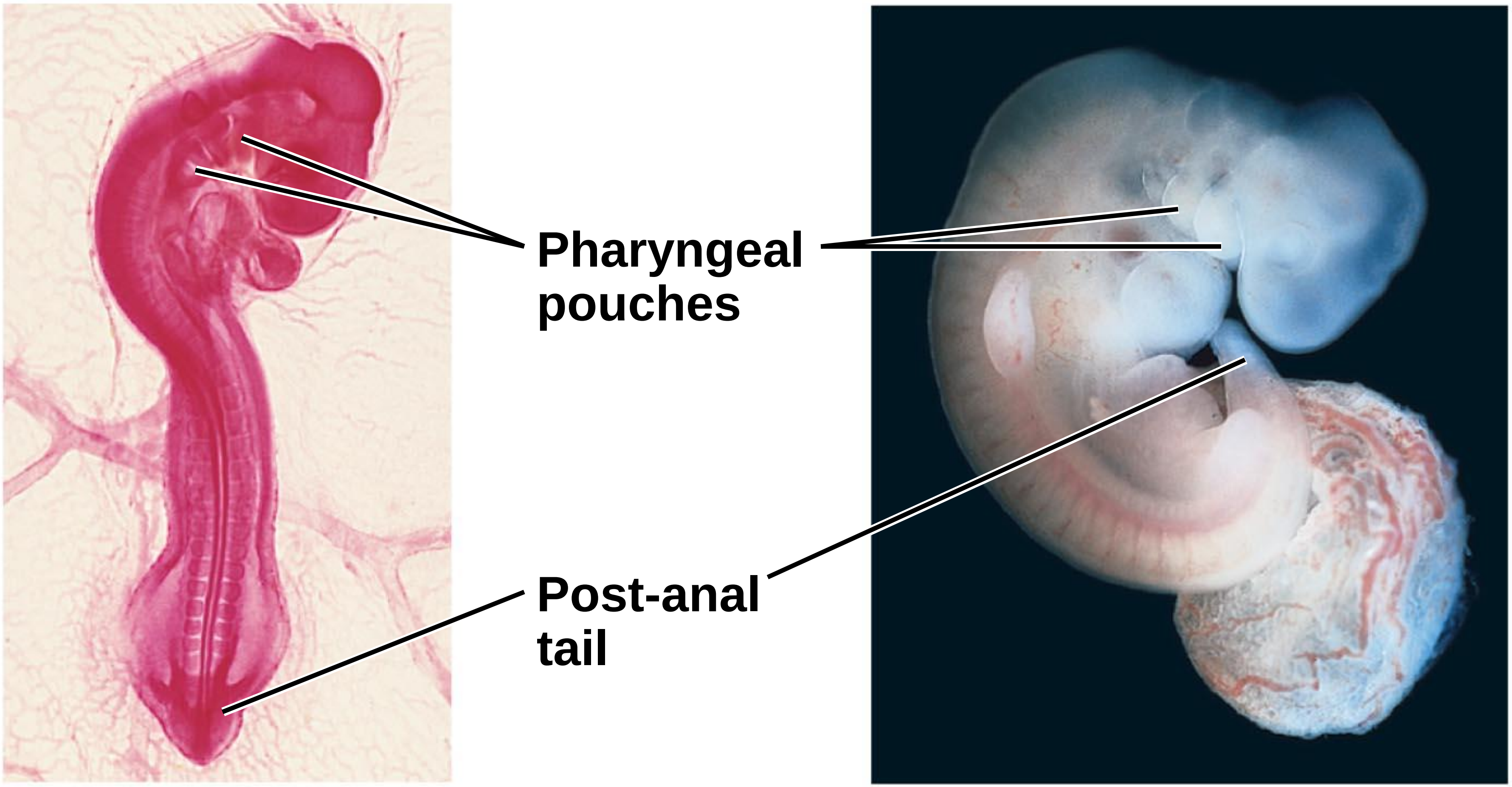
- Which of the following pairs are homologous structures?
  - Human limb and whale flipper
  - Insect wing and bat wing
  - Human thumb and chimpanzee thumb

13.5 A mass of other evidence reinforces the evolutionary view of life

- Which of the following are homologous structures?
  - Oak leaf and oak root
  - Oak leaf and lichen
  - Oak leaf and maple leaf
  - There are no homologous plant structures

13.5 A mass of other evidence reinforces the evolutionary view of life

- *Comparative embryology* is the comparison of early stages of development among different organisms
  - Many vertebrates have common embryonic structures, revealing homologies
  - When you were an embryo, you had a tail and pharyngeal pouches (just like an embryonic fish)

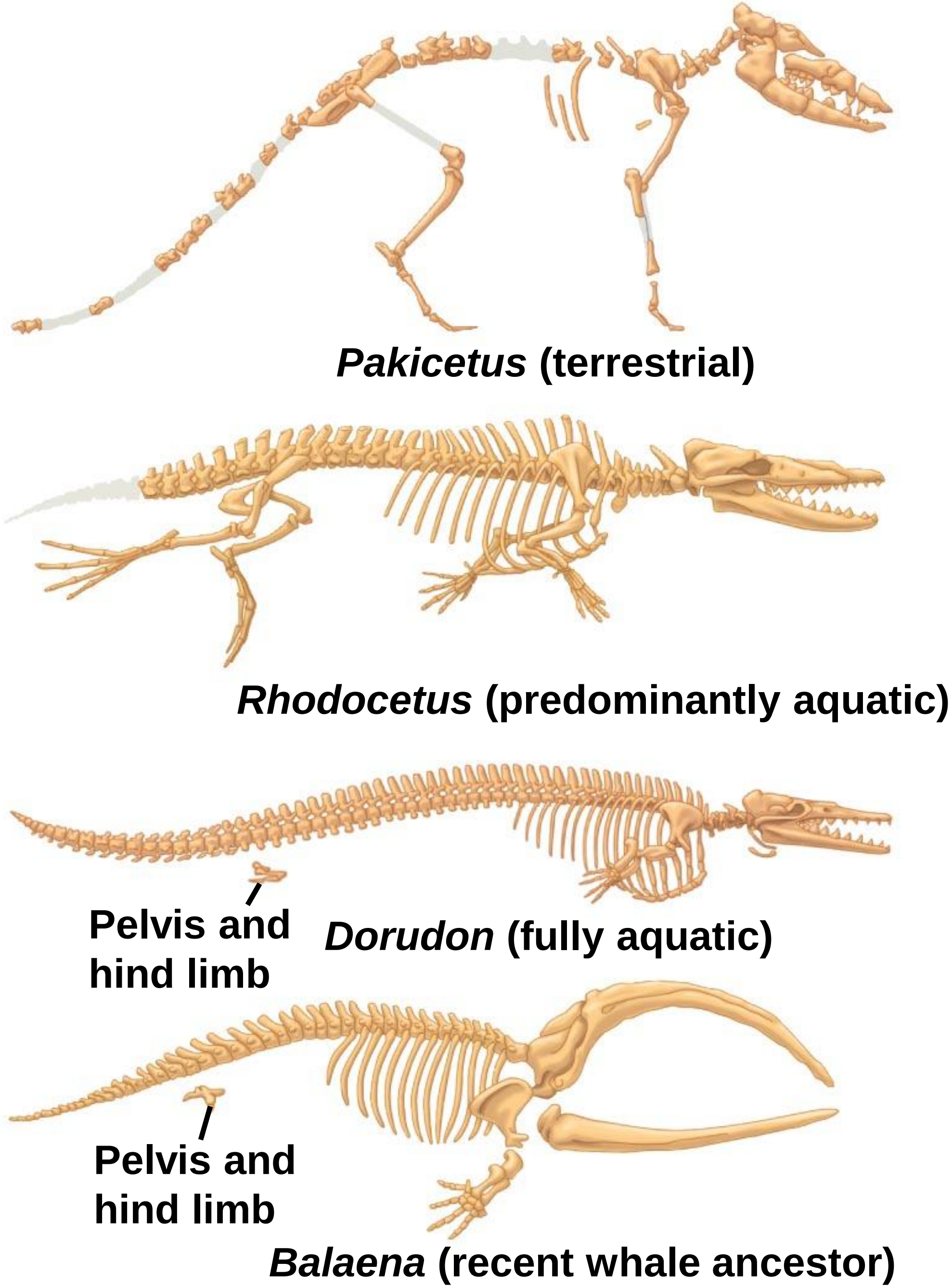


Chick embryo

Human embryo

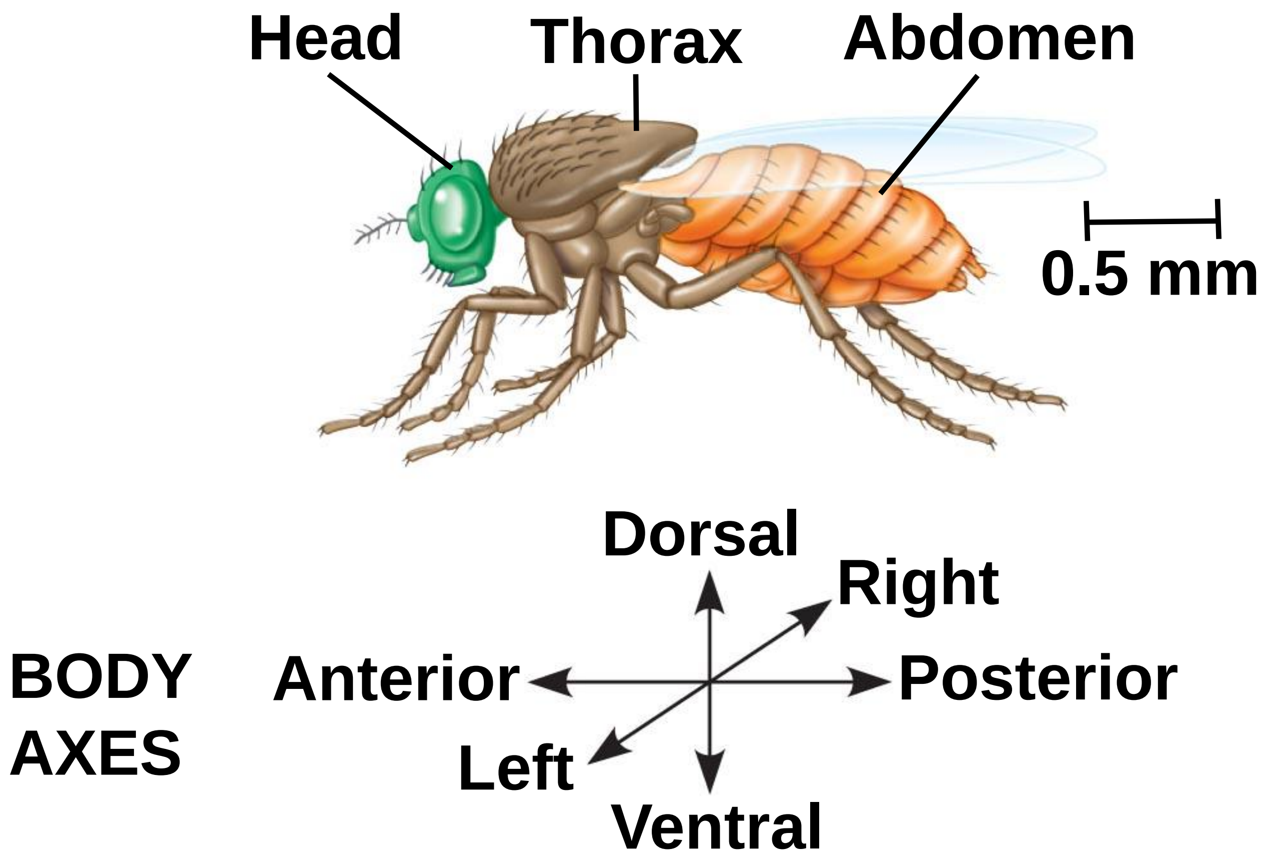
13.5 A mass of other evidence reinforces the evolutionary view of life

- Some homologous structures are vestigial organs
  - For example, the pelvic and hind-leg bones of some modern whales


Pakicetus (terrestrial)
Rhodocetus (predominantly aquatic)
Pelvis and hind limb
Dorudon (fully aquatic)
Pelvis and hind limb
Balaena (recent whale ancestor)

13.5 A mass of other evidence reinforces the evolutionary view of life

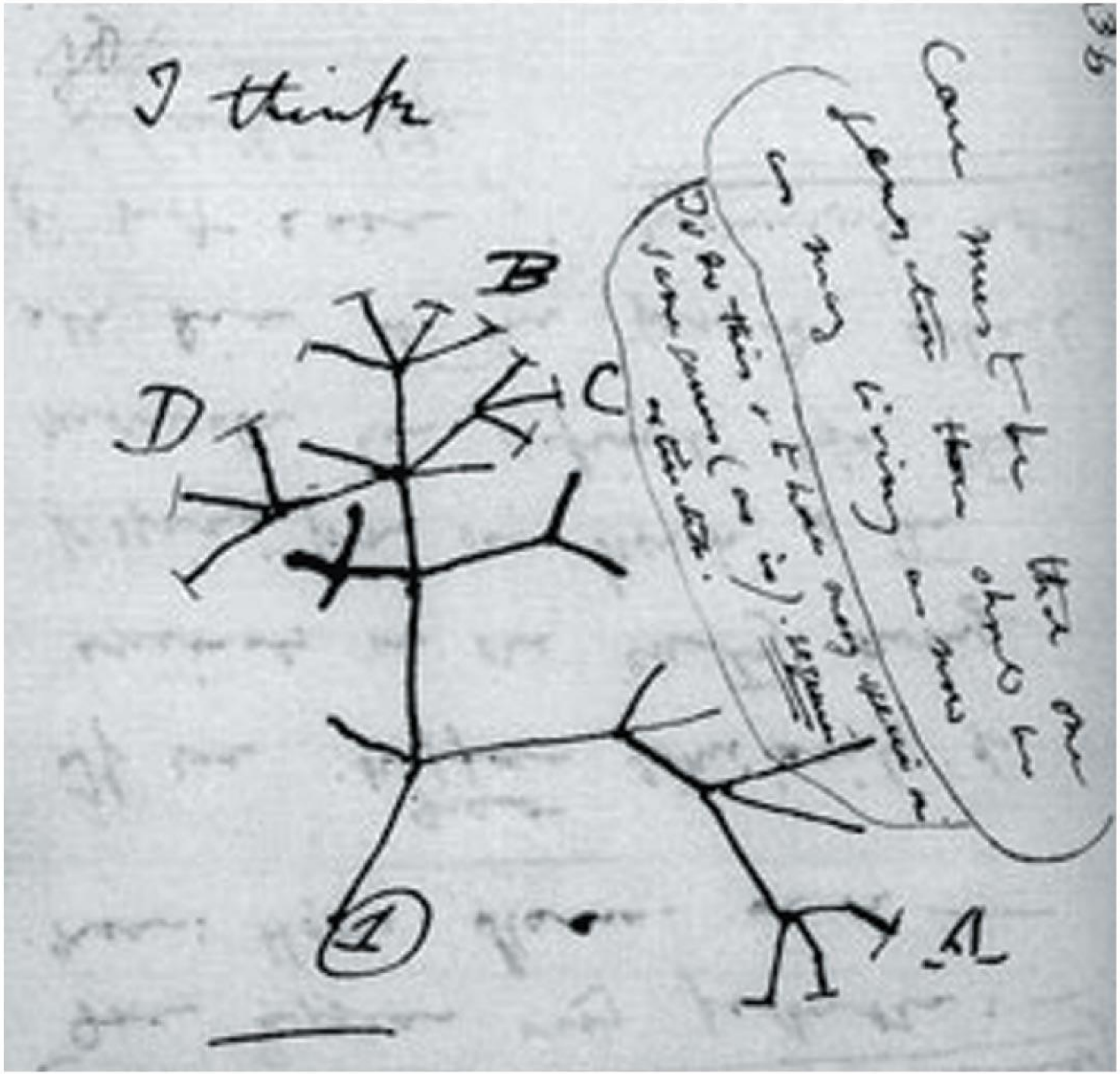
- **Molecular biology**: Comparisons of DNA and amino acid sequences between different organisms reveal evolutionary relationships
  - All living things share a common DNA code for the proteins found in living cells
  - We share genes with bacteria, yeast, and fruit flies


Head
Thorax
Abdomen
0.5 mm
Dorsal
Right
Anterior
Posterior
Left
Ventral
BODY
AXES

(a) Adult

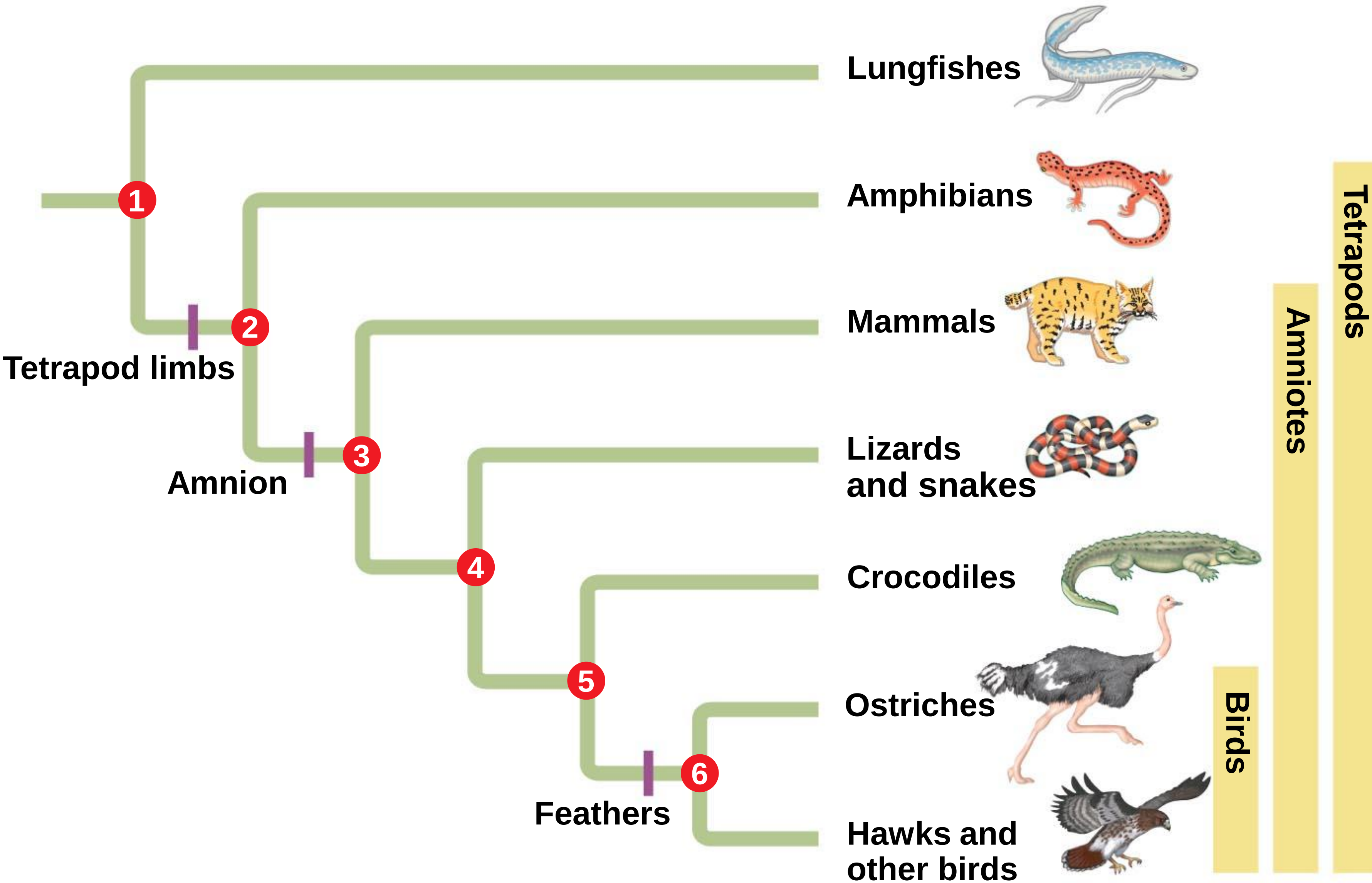
13.6 Homologies indicate patterns of descent that can be shown on an evolutionary tree

- Darwin was the first to represent the history of life as a tree


I think
1
A
B
C
D

13.6 Homologies indicate patterns of descent that can be shown on an evolutionary tree

- Homologous structures and genes can be used to determine the branching sequence of an evolutionary tree


1
2
3
4
5
6
Tetrapod limbs
Amnion
Feathers
Lungfishes
Amphibians
Mammals
Lizards and snakes
Crocodiles
Ostriches
Hawks and other birds
Birds
Amniotes
Tetrapods

THE EVOLUTION OF POPULATIONS

13.7 Populations are the units of evolution

- A **population** is a group of individuals of the same species living in the same place at the same time
- **Evolution** is the change in heritable traits in a population over generations
- Populations may be isolated from one another (with little interbreeding), or individuals within populations may interbreed

13.7 Populations are the units of evolution

- A **gene pool** is the total collection of genes in a population at any one time
- **Microevolution** is a change in the relative frequencies of alleles in a gene pool over time

13.7 Populations are the units of evolution

- **Population genetics** studies how populations change genetically over time
- The **modern synthesis** connects Darwin's theory with population genetics

13.8 Mutation and sexual reproduction produce genetic variation, making evolution possible

- **Mutation**, or changes in the nucleotide sequence of DNA, is the ultimate source of new alleles
  - Occasionally, mutant alleles improve the adaptation of an individual to its environment and increase its survival and reproductive success (for example, DDT resistance in insects)

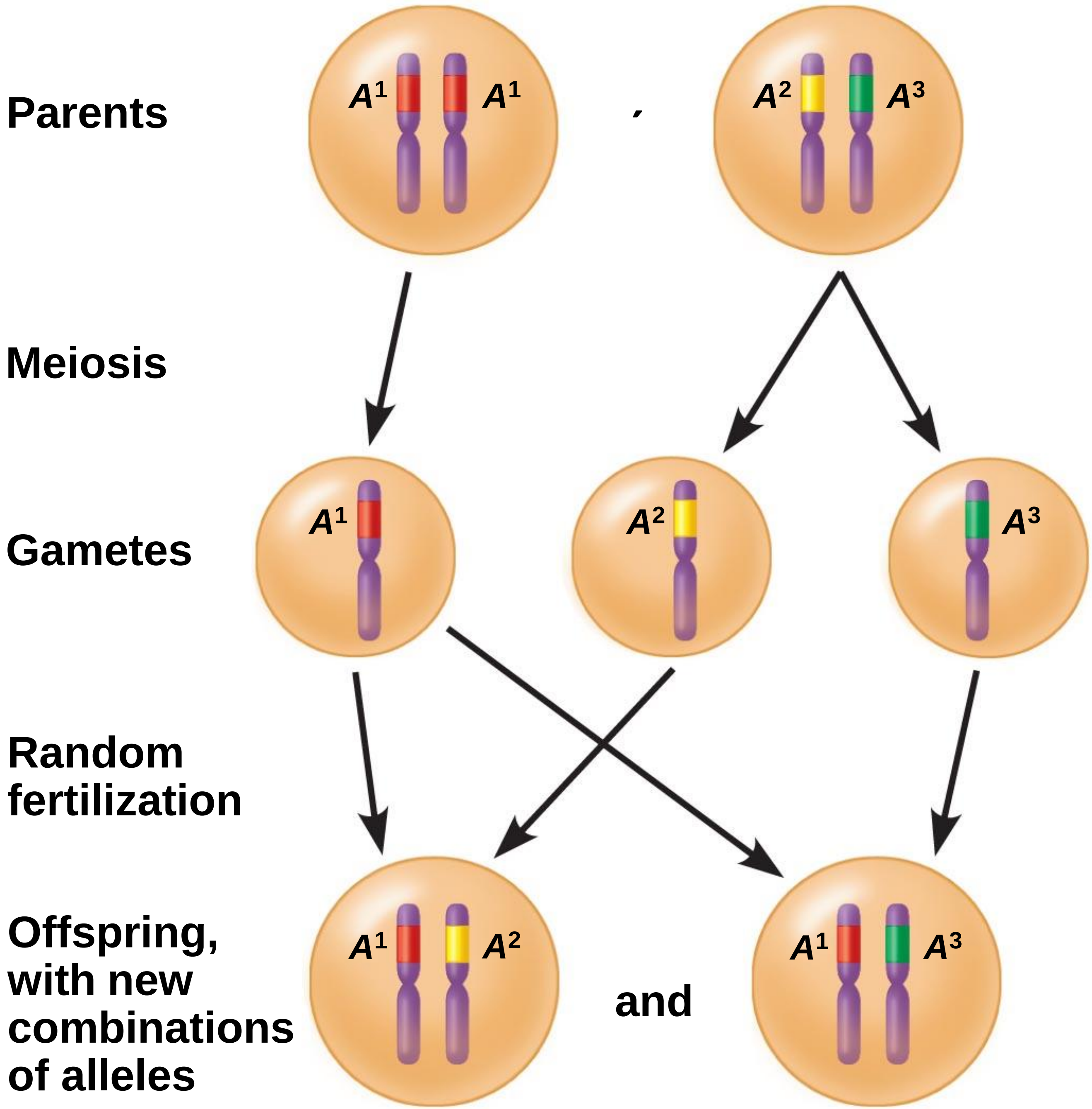
13.8 Mutation and sexual reproduction produce genetic variation, making evolution possible

- Chromosomal duplication is an important source of genetic variation
  - If a gene is duplicated, the new copy can undergo mutation without affecting the function of the original copy
  - For example, an early ancestor of mammals had a single gene for an olfactory receptor
  - The gene has been duplicated many times, and humans now have 1,000 different olfactory receptor genes

13.8 Mutation and sexual reproduction produce genetic variation, making evolution possible

- Sexual reproduction shuffles alleles to produce new combinations
  - Homologous chromosomes sort independently as they separate during anaphase I of meiosis
  - During prophase I of meiosis, pairs of homologous chromosomes cross over and exchange genes
  - Further variation arises when sperm randomly unite with eggs in fertilization

PLAY Animation: Genetic Variation from Sexual Recombination


Parents
A^1 A^1
A^2 A^3
Meiosis
Gametes
A^1
A^2
A^3
Random fertilization
Offspring, with new combinations of alleles
A^1 A^2
and
A^1 A^3

13.8 Mutation and sexual reproduction produce genetic variation, making evolution possible

- How many possible combinations of chromosomes are possible in a human sperm or egg due to independent assortment during meiosis?
  - 23 combinations
  - 46 combinations
  - 23^2 = 529 combinations
  - 2^{23} = ~ 8 million combinations

MECHANISMS OF MICROEVOLUTION

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- If the five conditions for the Hardy-Weinberg equilibrium are not met in a population, the population’s gene pool may change
  - **Mutations** are rare and random and have little effect on the gene pool
  - If **mating is nonrandom**, allele frequencies won’t change much (although genotype frequencies may)

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- The three main causes of evolutionary change are
  - Natural selection
  - Genetic drift
  - Gene flow

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- **Natural selection**
  - If individuals differ in their survival and reproductive success, natural selection will alter allele frequencies
  - Consider the boobies: Would webbed or nonwebbed boobies be more successful at swimming and capturing fish?

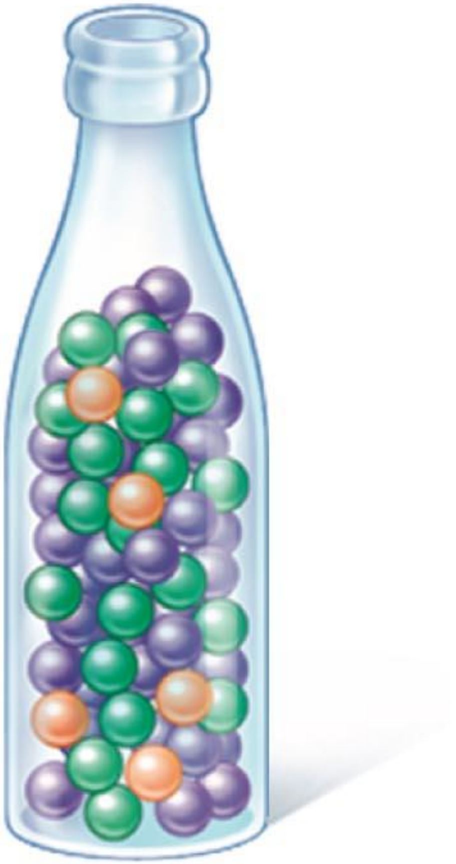
13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- **Genetic drift**
  - **Genetic drift** is a change in the gene pool of a population due to chance
  - In a small population, chance events may lead to the loss of genetic diversity

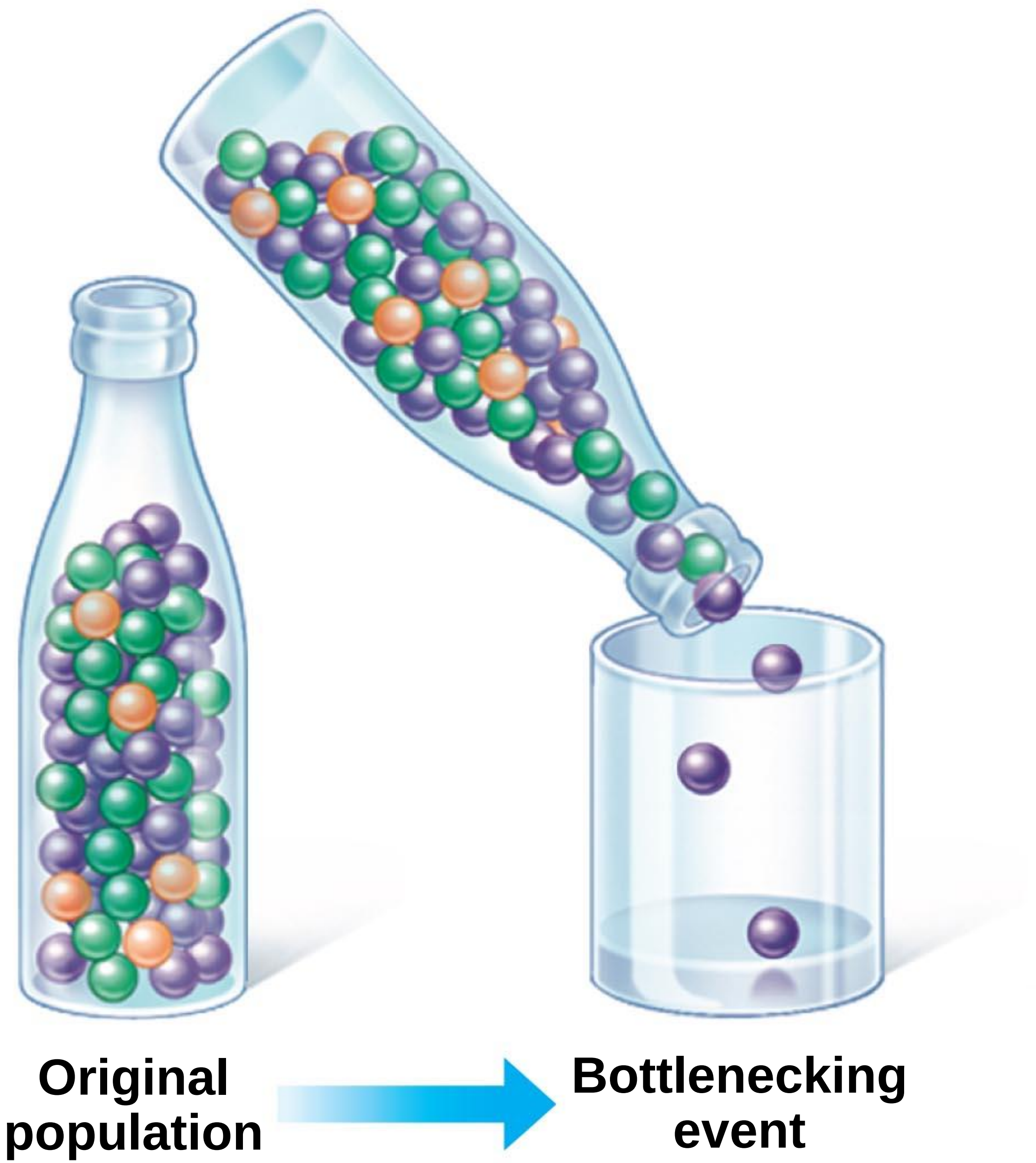
13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

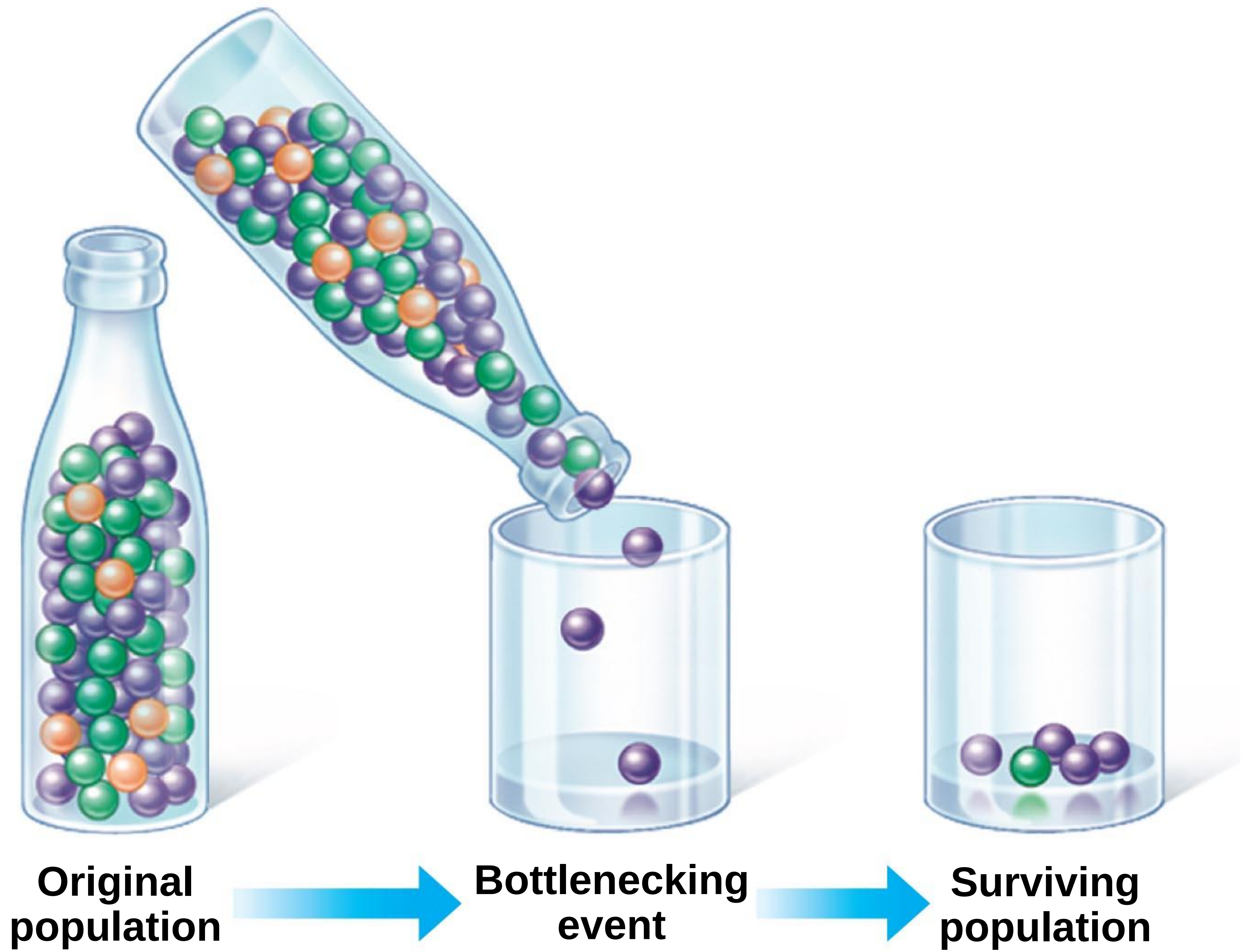
- **Genetic drift**
  - The **bottleneck effect** leads to a loss of genetic diversity when a population is greatly reduced
    - For example, the northern elephant seal was hunted to near extinction in the 1700s and 1800s
    - A remnant population of fewer than 100 seals was discovered and protected; the current population of 175,000 descended from those few seals and has virtually no genetic diversity

PLAY Animation: Causes of Evolutionary Change



Original population


Original
population
Bottlenecking
event


Original population
Bottlenecking event
Surviving population

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- **Genetic drift**
  - Genetic drift produces the **founder effect** when a few individuals colonize a new habitat
    - The smaller the group, the more different the gene pool of the new population will be from the gene pool of the original population

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- **Gene flow**
  - **Gene flow** is the movement of individuals or gametes/spores between populations and can alter allele frequencies in a population

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

- Four moose were taken from the Canadian mainland to Newfoundland in 1904. These two males and two females rapidly formed a large population of moose that now flourishes in Newfoundland. Which mechanism is most likely to have contributed to the genetic differences between the mainland and Newfoundland moose?
  - Gene flow
  - Founder effect
  - Novel mutations

13.11 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

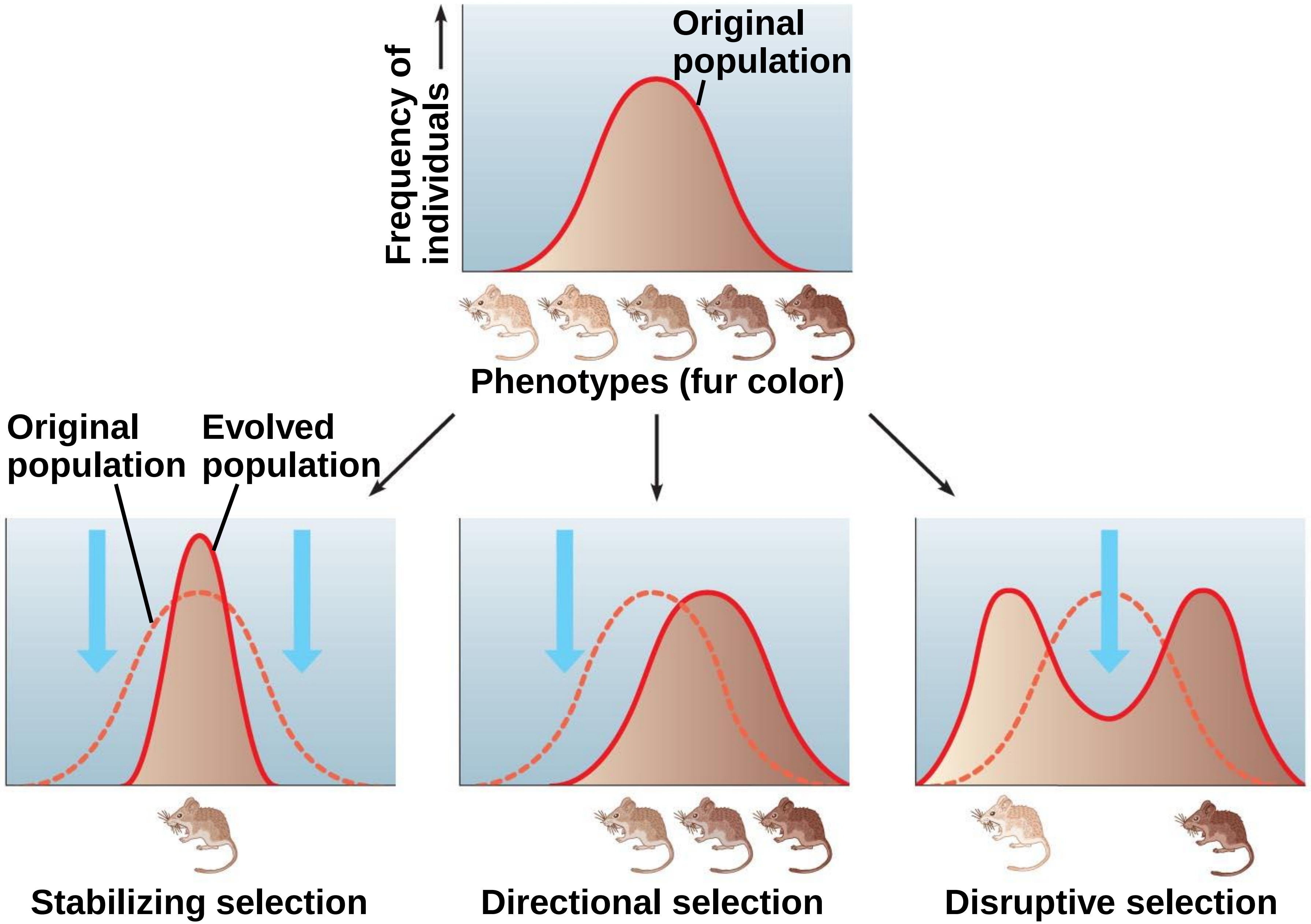
- The fossil remains of pygmy (or dwarf) mammoths (1.5 m to 2 m tall) have been found on Santa Rosa and San Miguel Islands off the coast of California. This population of pygmy mammoths is descended from a population of mammoths of normal size (4 m tall). Dwarfing is common in island populations and **is not the result of chance events**. What mechanism do you think best accounts for the decrease in mammoth size on these islands?
  - Gene flow
  - Genetic drift
  - Natural selection

13.12 Natural selection is the only mechanism that consistently leads to adaptive evolution

- An individual's fitness is the contribution it makes to the gene pool of the next and subsequent generations
- The fittest individuals are those that pass on the most genes to the next generation

13.13 Natural selection can alter variation in a population in three ways

- **Stabilizing selection** favors intermediate phenotypes, acting against extreme phenotypes
- Stabilizing selection is very common, especially when environments are stable


Frequency of individuals
Original population
Phenotypes (fur color)
Original population
Evolved population
Stabilizing selection
Directional selection
Disruptive selection

13.13 Natural selection can alter variation in a population in three ways

- Example of stabilizing selection
  - In Swiss starlings, clutch size varies from 1 to 8; the average clutch size is 4
  - Researchers marked chicks from different clutch sizes and recaptured fledglings after 3 months
  - Birds from clutches with 3, 4, or 5 birds had higher recapture rates than birds from clutches of 1 or 2 or 6, 7, or 8

13.13 Natural selection can alter variation in a population in three ways

- **Directional selection** acts against individuals at one of the phenotypic extremes
- Directional selection is common during periods of environmental change, or when a population migrates to a new and different habitat

13.13 Natural selection can alter variation in a population in three ways

- **Disruptive selection** favors individuals at both extremes of the phenotypic range
  - This form of selection may occur in patchy habitats

13.14 Sexual selection may lead to phenotypic differences between males and females

- In many animal species, males and females show distinctly different appearance, called **sexual dimorphism**
- **Intrasexual competition** involves competition for mates, usually by males

13.14 Sexual selection may lead to phenotypic differences between males and females

- In **intersexual competition** (or mate choice), individuals of one sex (usually females) are choosy in picking their mates, often selecting flashy or colorful mates

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- The excessive use of antibiotics is leading to the evolution of antibiotic-resistant bacteria
- As a result, natural selection is favoring bacteria that are resistant to antibiotics
  - Natural selection for antibiotic resistance is particularly strong in hospitals
  - Many hospital-acquired infections are resistant to a variety of antibiotics

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- The fruit fly *Drosophila melanogaster* has an allele that confers resistance to DDT and similar insecticides
- Laboratory strains of *D. melanogaster* have been established from flies collected in the wild in the 1930s (before the widespread use of insecticides) and the 1960s (after 20 years of DDT use)

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- Lab strains established in the 1930s have no alleles for DDT resistance; in lab strains established in the 1960s, the frequency of the DDT-resistance allele is 37%

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- Some fruit flies evolved resistance to DDT in order to survive—true or false?

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- Fruit flies became more resistant to DDT over time—true or false?

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- When DDT was widely used, fruit flies with DDT resistance had greater evolutionary fitness than fruit flies lacking DDT resistance—true or false?

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- Alleles for DDT resistance may have been present but rare prior to DDT use—true or false?

13.15 EVOLUTION CONNECTION: The evolution of antibiotic resistance in bacteria is a serious public health concern

- Alleles for DDT resistance arose by mutation during the period of DDT use because of selection for pesticide resistance—true or false?

13.17 Natural selection cannot fashion perfect organisms

1. Selection can only act on existing variation
   - Natural selection cannot conjure up new beneficial alleles
2. Evolution is limited by historical constraints
   - Birds arose as the forelimb of a small dinosaur evolved into a wing

13.17 Natural selection cannot fashion perfect organisms

3. Adaptations are often compromises
4. Chance, natural selection and the environment interact

You should now be able to

1. Describe Darwin's concept of natural selection
2. Describe two examples of natural selection known to occur in nature
3. Explain how the fossil record, biogeography, comparative anatomy, comparative embryology, and molecular biology support evolution
4. Explain how mutation and sexual recombination produce genetic variation
5. Describe the five conditions required for a population to be in Hardy-Weinberg equilibrium

You should now be able to

6. Explain the significance of the Hardy-Weinberg equilibrium to natural populations and to public health science
7. Define genetic drift and gene flow
8. Explain why natural selection is the only mechanism that leads to adaptive evolution
9. Distinguish between stabilizing selection, directional selection, and disruptive selection, and describe an example of each

You should now be able to

10. Distinguish between intrasexual selection and intersexual selection
11. Describe how antibiotic resistance has evolved
12. Explain how genetic variation is maintained in populations