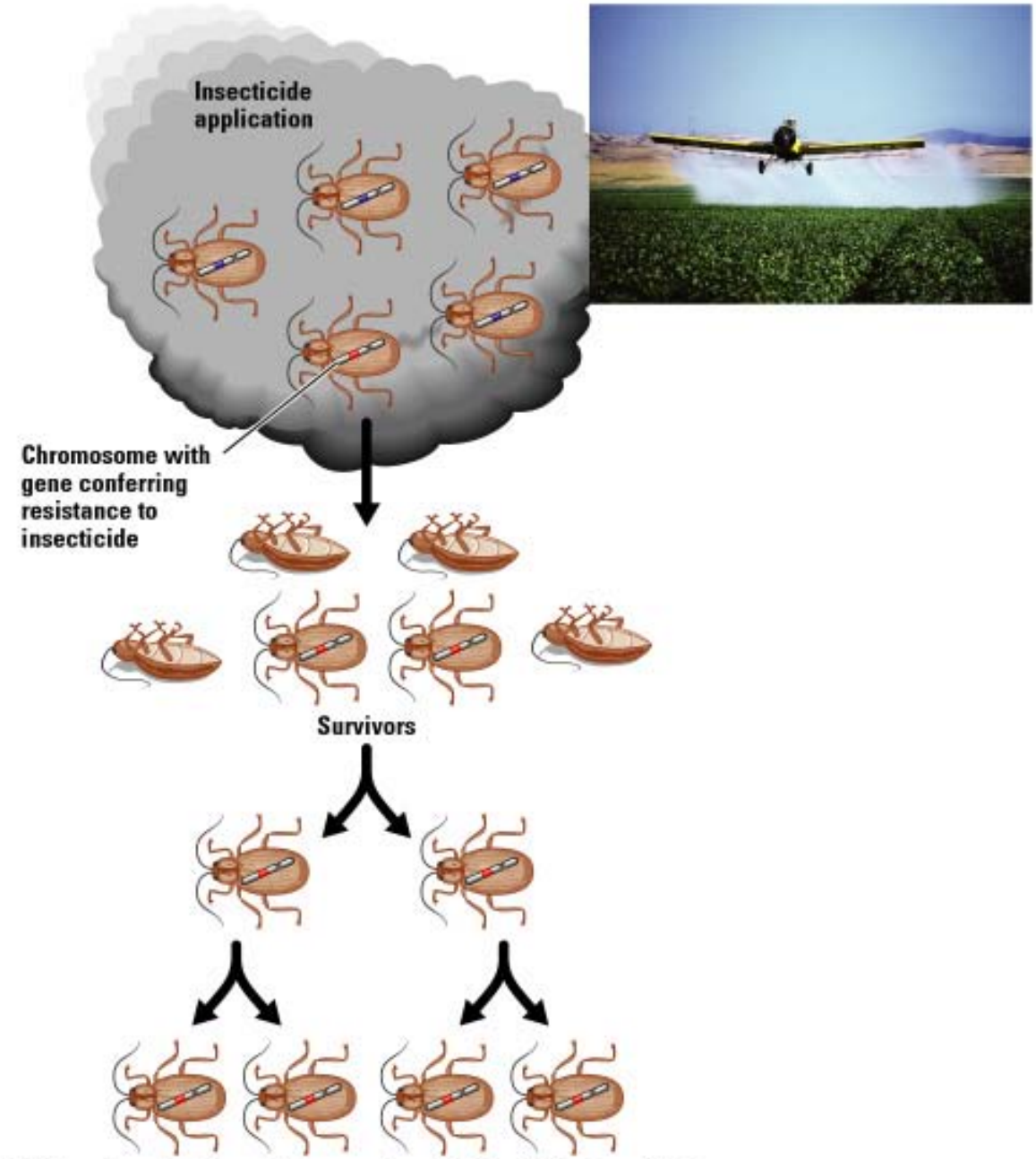
Evolution

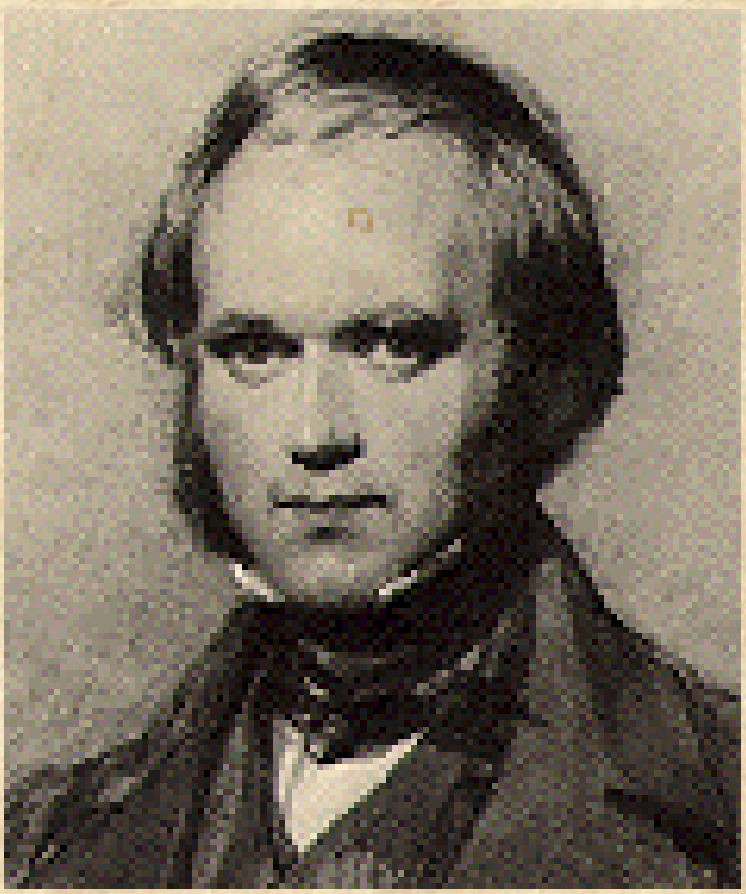
- Evolution Exists
  - Mosquitoes and DDT
  - Bacteria and Antibiotics
- Theory Applies to Mechanism

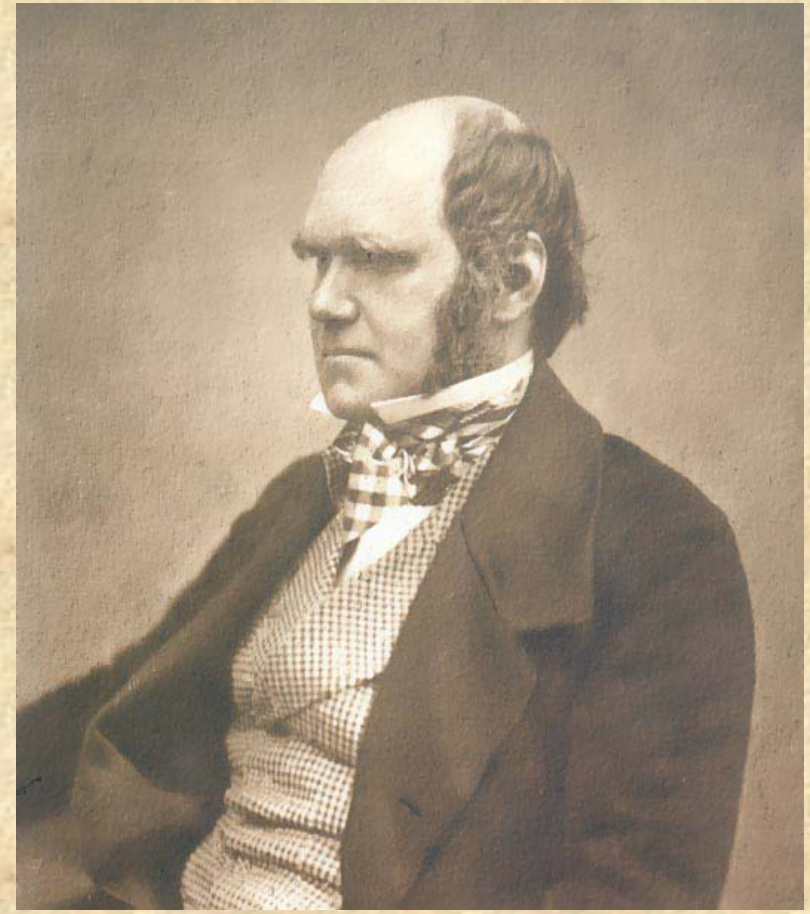


Additional applications of the same insecticide will be less effective, and the frequency of resistant insects in the population will grow

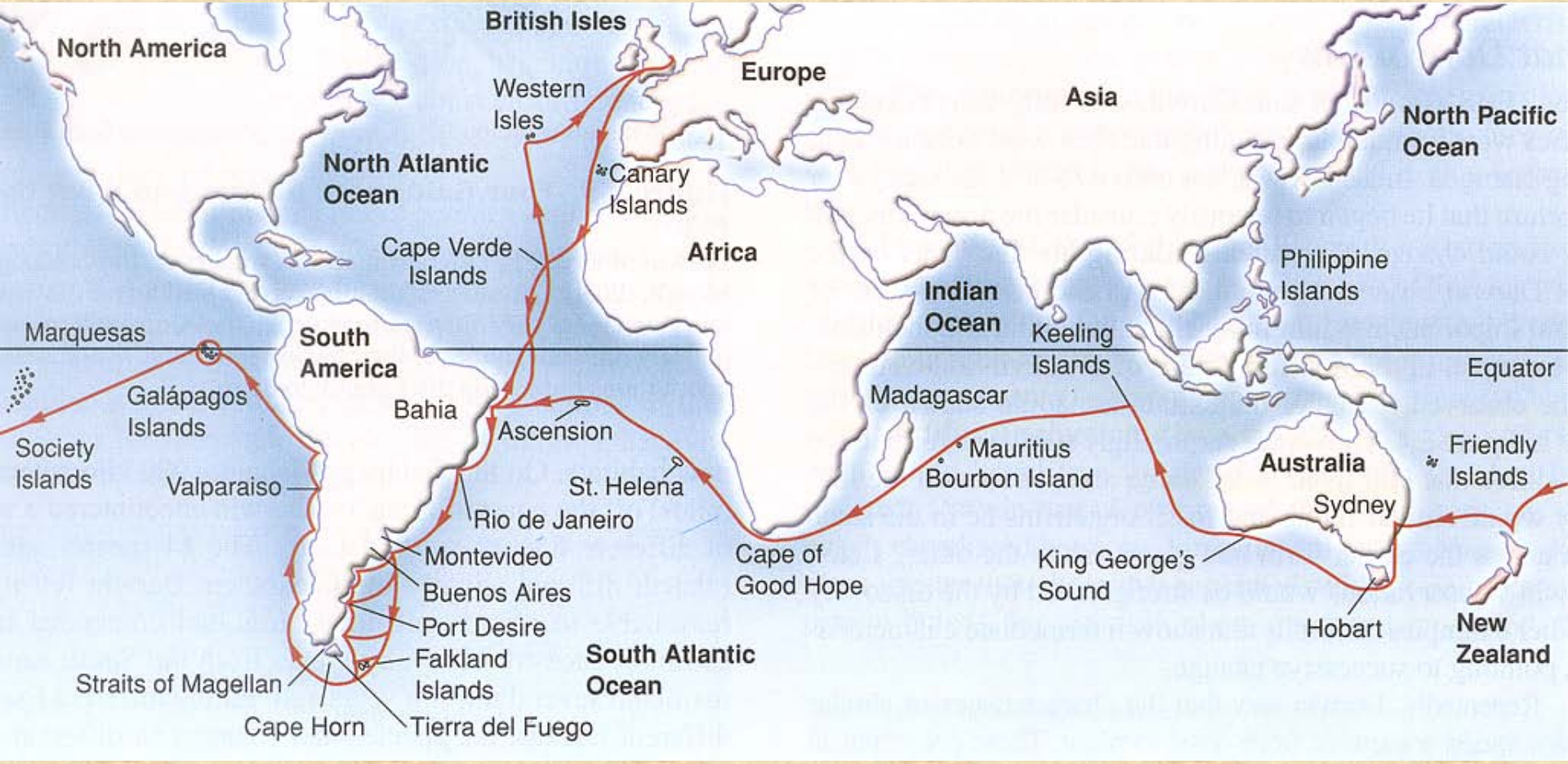
Evolution Exists

Evolution: Charles Darwin

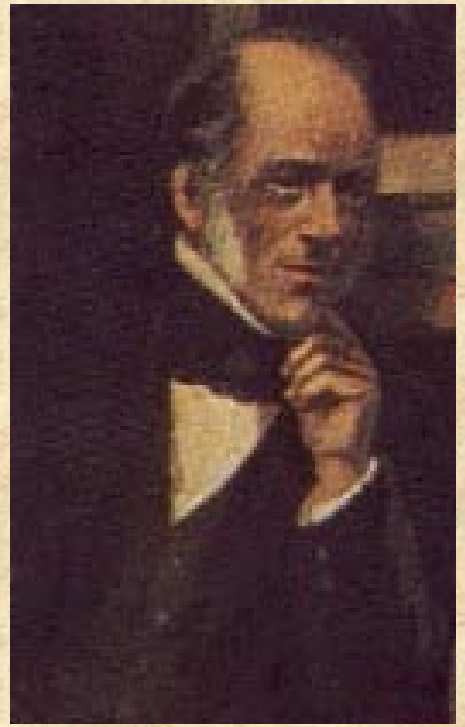




The Voyage of the Beagle



Charles Lyell (1797 – 1875)



Wrote: *Principles of Geology*

- The earth changes by gradual processes
- The Earth is Very Old – Geologic Time

Charles Lyell – A Geologist

The Earth is Very Old

- Literal translation of the bible
  - Archbishop James Ussher
    - The Earth Originated 4004 B.C.

- Lyell, in his book *Principles of Geology*, gave Darwin the time frame to explain changes he observed in the fossil record.

The Grand Canyon

Relatively young rock layers

Older rock layers

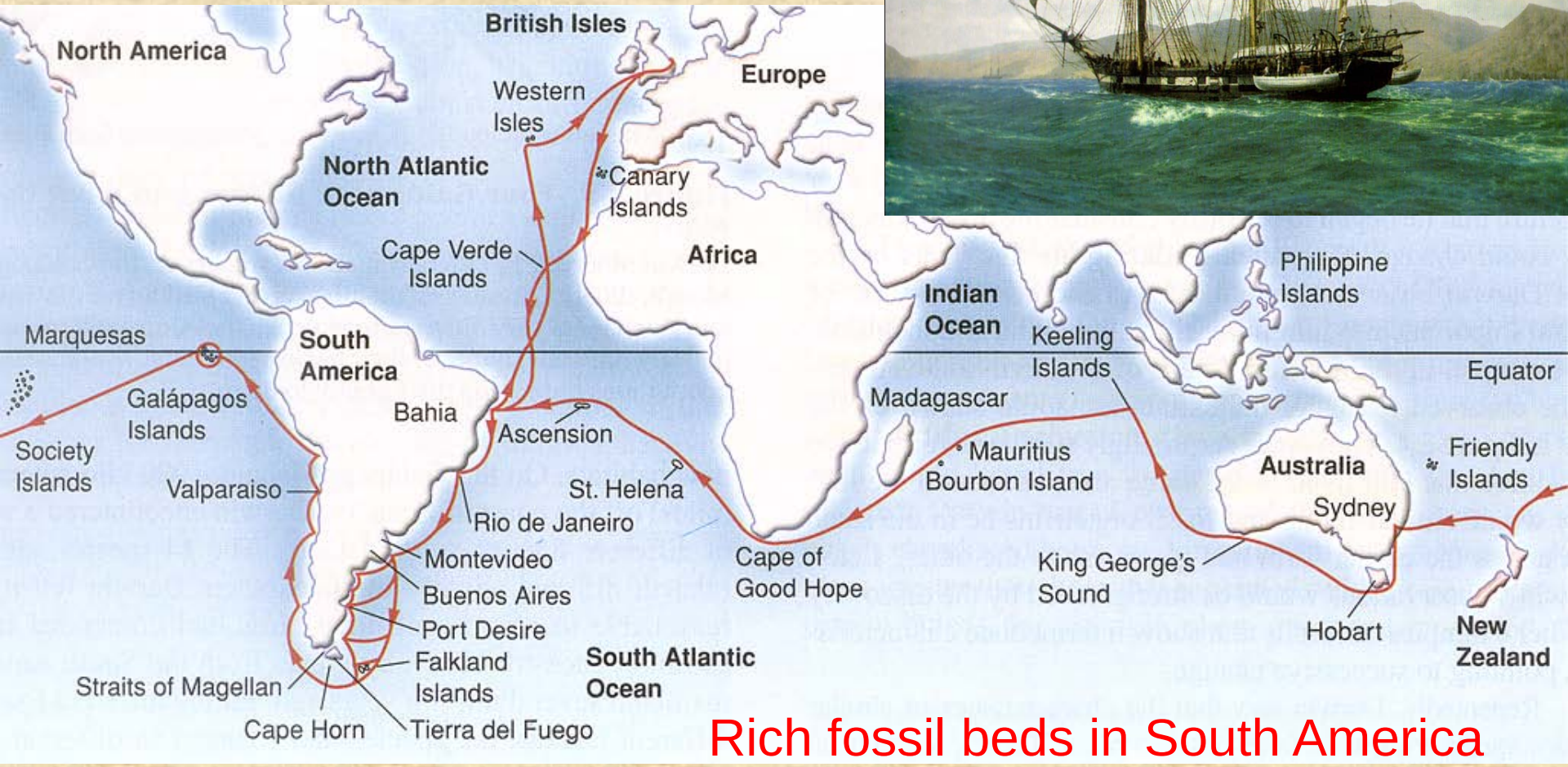
Very old rock layers

The Grand Canyon was created by the Colorado River

Era	Period	Epoch	MYA	Plant and Animal Life
		Holocene	0–0.01	AGE OF HUMAN CIVILIZATION; Destruction of tropical rain forests accelerates extinctions.
				SIGNIFICANT MAMMALIAN EXTINCTION
	Neogene	Pleistocene	0.01–2	Modern humans appear; modern plants spread and diversify.
		Pliocene	2–6	First hominids appear; modern angiosperms flourish.
		Miocene	6–24	Apelike mammals, grazing mammals, and insects flourish; grasslands spread; and forests contract.
Cenozoic*		Oligocene	24–37	Monkeylike primates appear; modern angiosperms appear.
	Paleogene	Eocene	37–58	All modern orders of mammals are present; subtropical forests flourish.
		Paleocene	58–65	Primates, herbivores, carnivores, insectivores are present; angiosperms diversify.
				MASS EXTINCTION: DINOSAURS AND MOST REPTILES
	Cretaceous		65–144	Placental mammals and modern insects appear; angiosperms spread and conifers persist.
	Jurassic		144–208	Dinosaurs flourish; birds and angiosperms appear.
Mesozoic				MASS EXTINCTION
	Triassic		208–250	First mammals and dinosaurs appear; forests of conifers and cycads dominate land; corals and molluscs dominate seas.
				MASS EXTINCTION
	Permian		250–286	Reptiles diversify; amphibians decline; and gymnosperms diversify.
	Carboniferous		286–360	Amphibians diversify; reptiles appear; and insects diversify. Age of great coal-forming forests.
				MASS EXTINCTION
	Devonian		360–408	Jawed fishes diversify; insects and amphibians appear; seedless vascular plants diversify and seed plants appear.
Paleozoic	Silurian		408–438	First jawed fishes and seedless vascular plants appear.
				MASS EXTINCTION
	Ordovician		438–510	Invertebrates spread and diversify; jawless fishes appear; nonvascular plants appear on land.
	Cambrian		510–543	Marine invertebrates with skeletons are dominant and invade land, and marine algae flourish.
			600	Oldest soft-bodied invertebrate fossils
			1,400–700	Protists evolve and diversify.
			2,000	Oldest eukaryotic fossils
Precambrian time			2,500	O_2 accumulates in atmosphere
			3,500	Oldest known fossils (prokaryotes)
			4,500	Earth forms.

Geologic Time Table

The Voyage of the Beagle



Rich fossil beds in South America

In January, 1834, Darwin finds many species of extinct Pleistocene mammals in Patagonia. All appeared to be giant varieties of present day mammals in in the same area.

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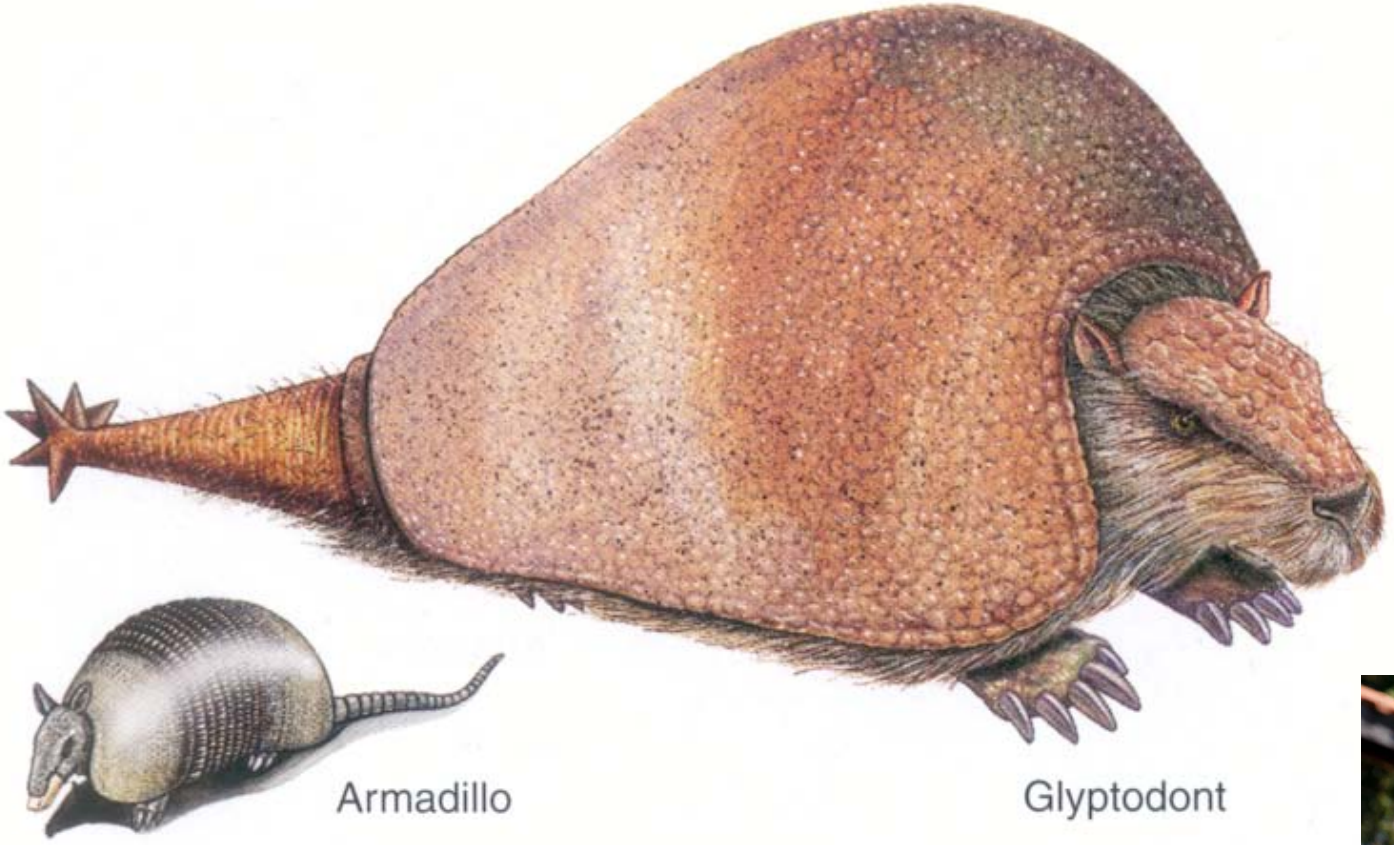
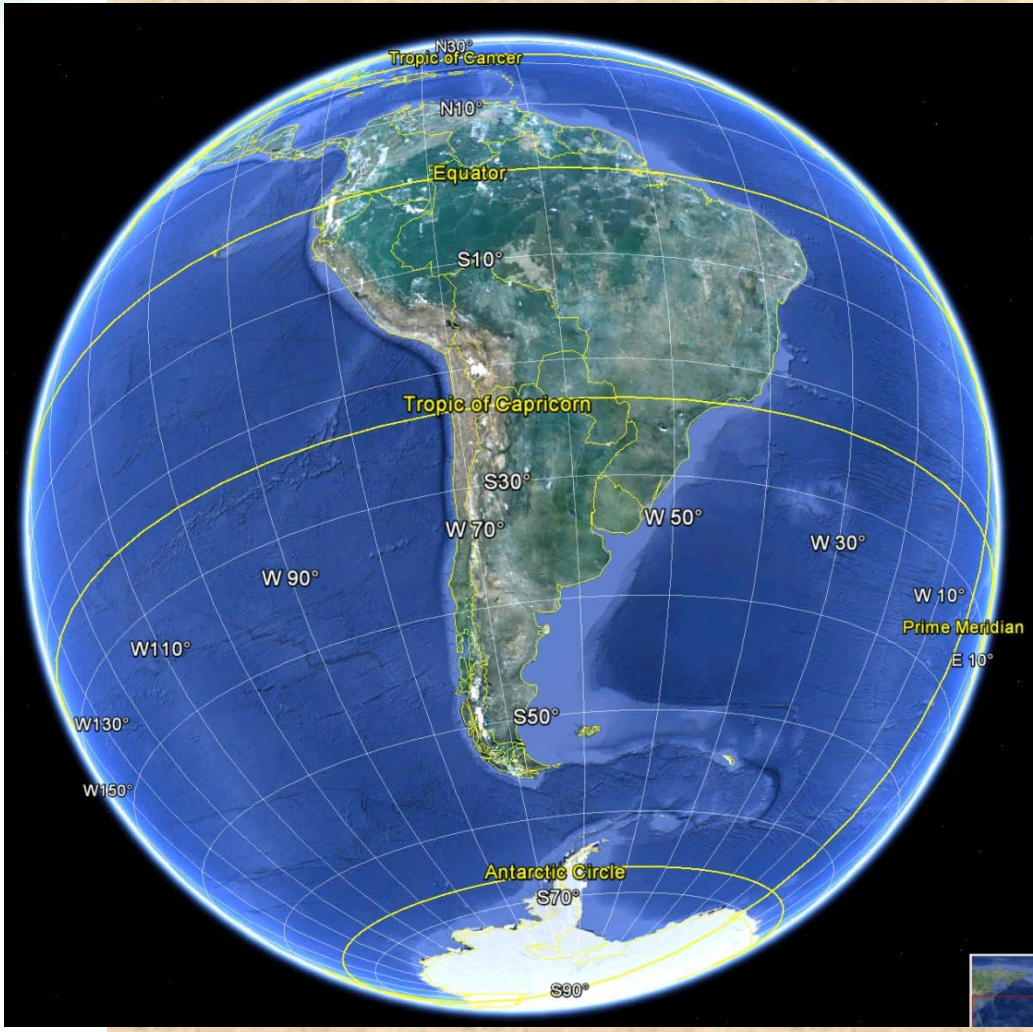
				MASS EXTINCTION: DINOSAURS AND MOST REPTILES

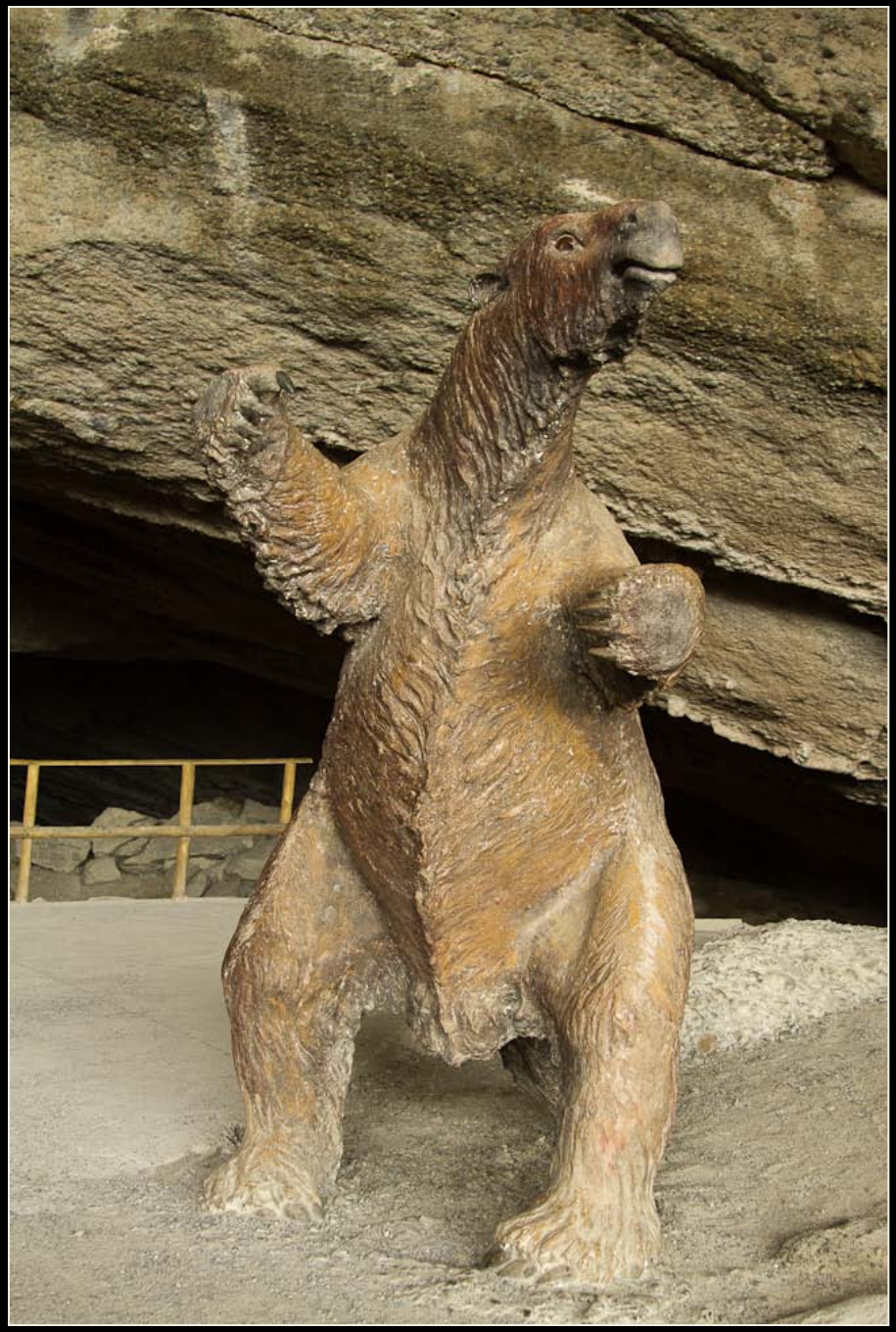


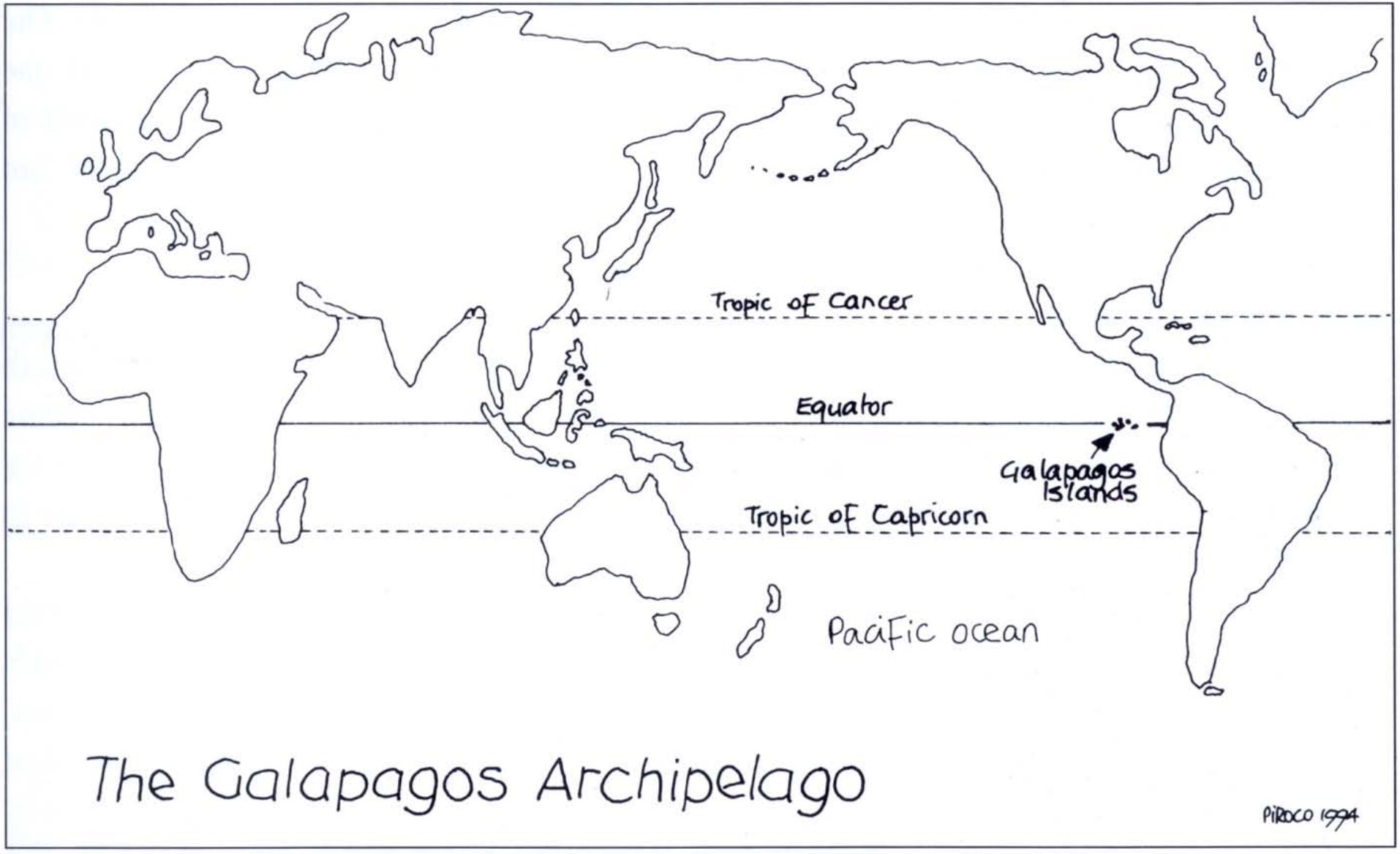
Glyptodont: Extinct 2,000 kilogram South American armadillo

Modern armadillo: 4.5 kilograms

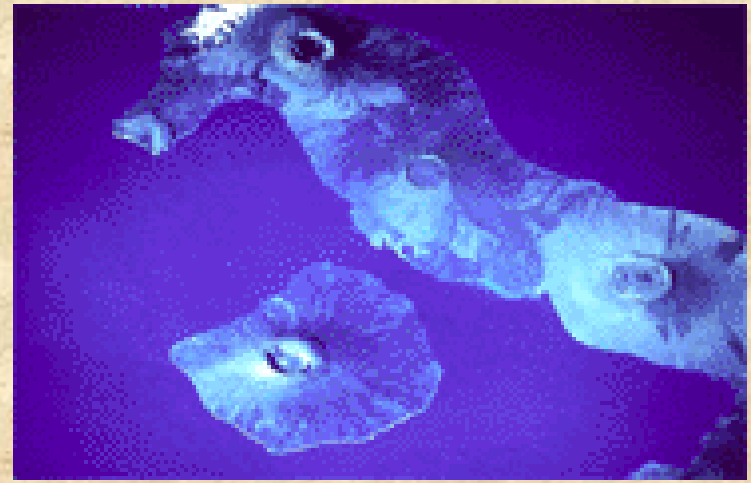

Bío-Bío
Cordillera del Viento
Copahue Volcano
9,777 ft 2,980 m
Las Lajas
Neuquén
Colorado
Villa El Chocón
Negro
CHILE
ARGENTINA
Viedma
Puerto Montt
Valdés Peninsula
Puerto Madryn
Trelew
-131 ft
-40 m
Nuevo Gulf
Chubut
Los Altares
Punta Clara
PACIFIC OCEAN
PATAGONIA
ATLANTIC OCEAN
Cerro Hudson
(Mount Hudson)
6,250 ft 1,905 m
Perito Moreno
Puerto Deseado
Monte Fitz Roy
11,073 ft 3,375 m
San Julián
LOS GLACIARES (GLACIERS) N.P.
Santa Cruz
Puerto Santa Cruz
Moreno Glacier
MONTE LEÓN NATIONAL PARK
Lake Argentino
TORRES DEL PAINE N.P.
Puerto Natales
Río Gallegos
Strait of Magellan
Falkland Islands
(Islas Malvinas)
(U.K.)
Punta Arenas
Tierra del Fuego
Ushuaia
0 mi 200
0 km 200
NATIONAL GEOGRAPHIC MAPS
Beagle Channel
Cape Horn
SOUTH AMERICA
CHILE
Santiago
Buenos Aires
ARGENTINA
AREA ENLARGED


N30°
Tropic of Cancer
N10°
Equator
S10°
Tropic of Capricorn
S30°
W 70°
W 50°
W 30°
W 90°
W 10°
Prime Meridian
E 10°
W110°
W130°
W150°
S50°
Antarctic Circle
S70°
S90°




Tropic of Cancer
Equator
Galapagos Islands
Tropic of Capricorn
Pacific ocean
The Galapagos Archipelago
PIROCO 1994

The Galapagos Islands



- Darwin collected 14 species of finches, some of which were only found on a single island.

- Were the islands colonized by animals that strayed from the mainland and then diversified on different islands?

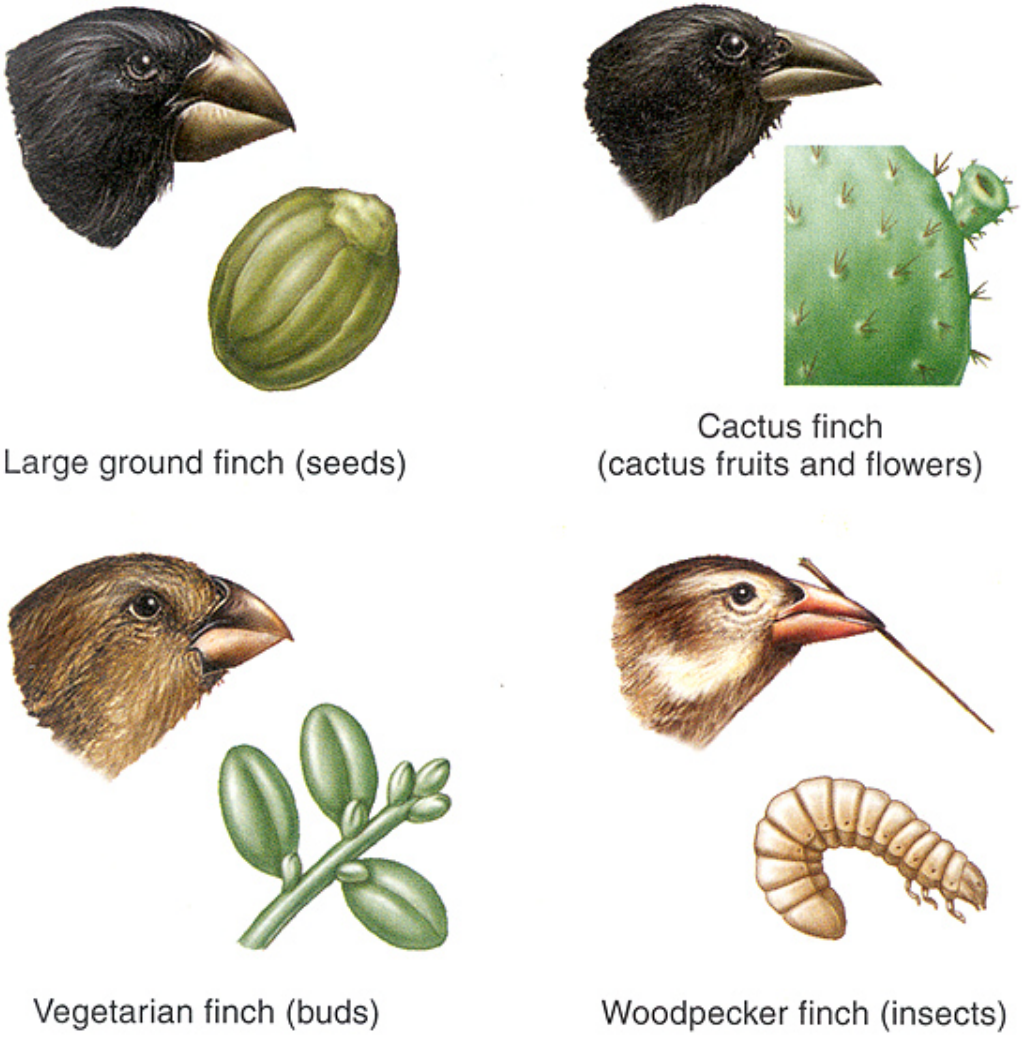


Figure 2.5 Four Galápagos finches and what they eat.

Darwin observed 14 different species of finches on the Galápagos Islands, differing mainly in their beaks and feeding habits. These four finches eat very different food items, and Darwin surmised that the very different shapes of their beaks represented evolutionary adaptations improving their ability to do so.

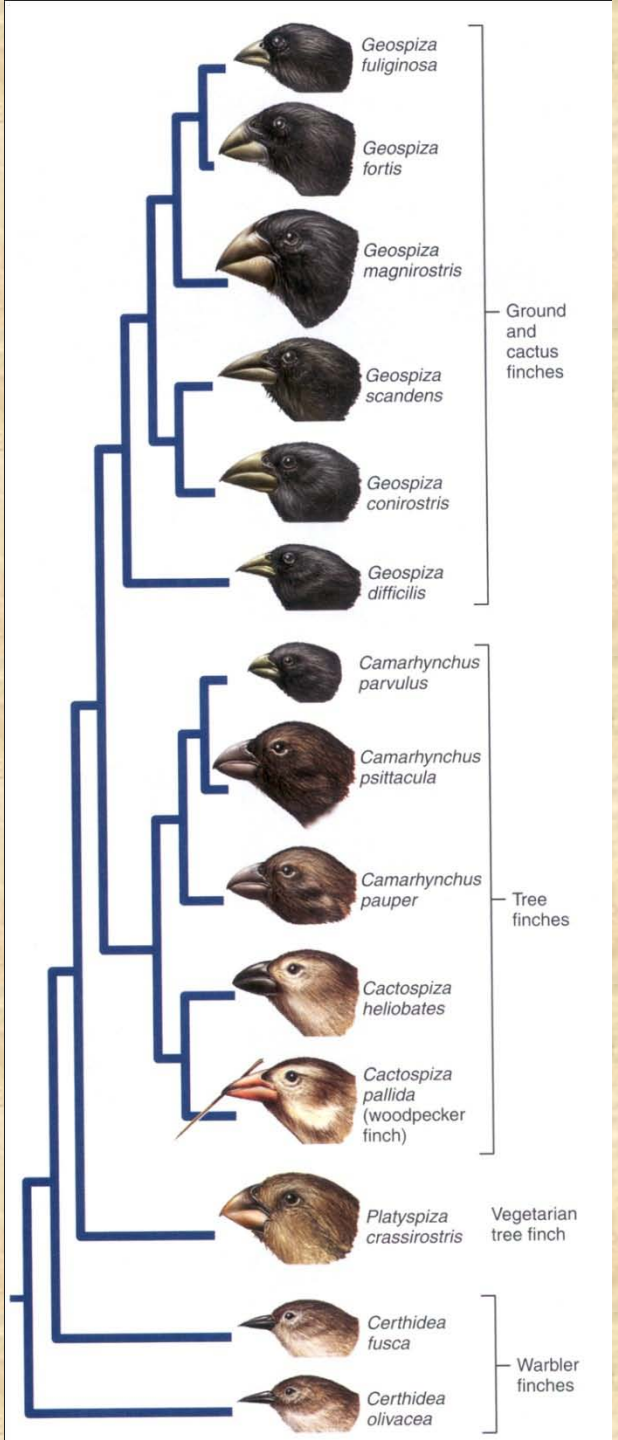
Woodpecker Finch

A Woodpecker Finch Uses a Cactus Spine to Pick Grub from a Tree

Galapagos Finches: Ground Finches

The cactus finch is one of the species of ground finches that is found on the Galapagos Islands

- The vampire finch is a type of ground finch
- In times of drought it punctures the tail or wings of nesting seabirds to drink their blood when food and moisture are scarce

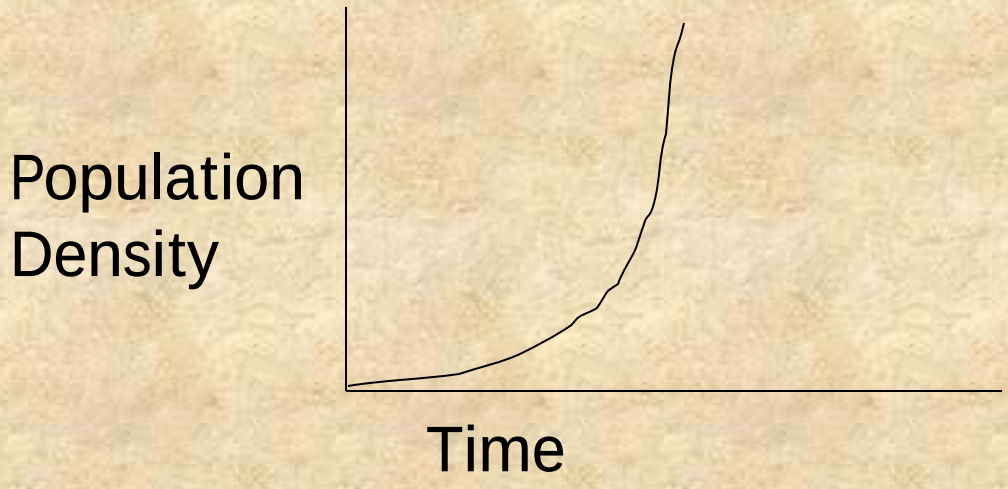


This family tree was constructed by comparing DNA of the 14 species of finches. It suggests that warbler finches were the first to evolve on the Galapagos

Thomas Malthus: "J-Shaped Curve"

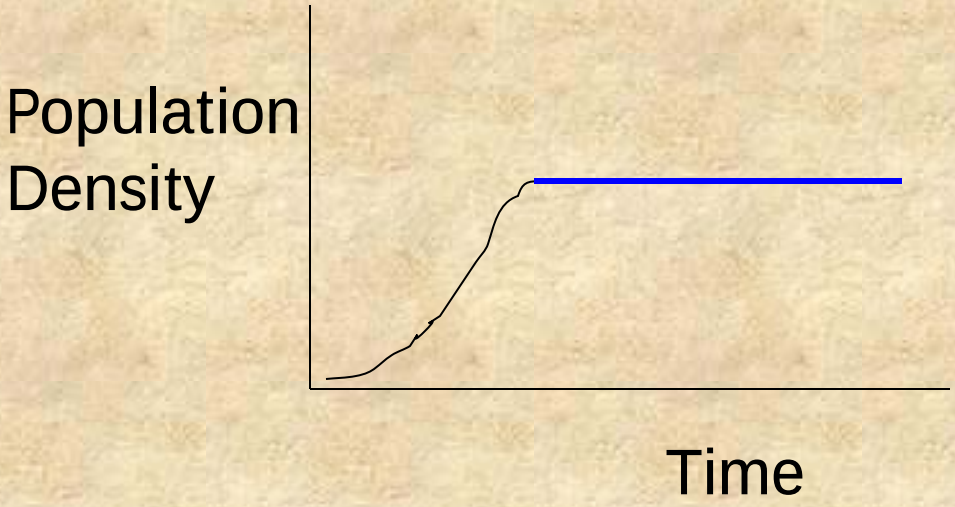
How many offspring?

- Populations are capable of of exponential growth
  - Populations produce more offspring than the environment can support.



Populations produce more offspring than will survive and reproduce. Less than 10% of these baby sea turtles will survive to reproduce.

Sigmoid Curve



- Organisms are capable of exponential growth.
- Carrying Capacity: The number of individuals the environment can support.

Most Populations in Nature Stabilize Around Some Mean Population Density Since Resources Are Limited

Variation Exists in Populations
Individual Differences are Inherited

Common Rock Dove

Capuchine

Variation Exists in Populations
Individual Differences are Inherited

Fantail

Helmet

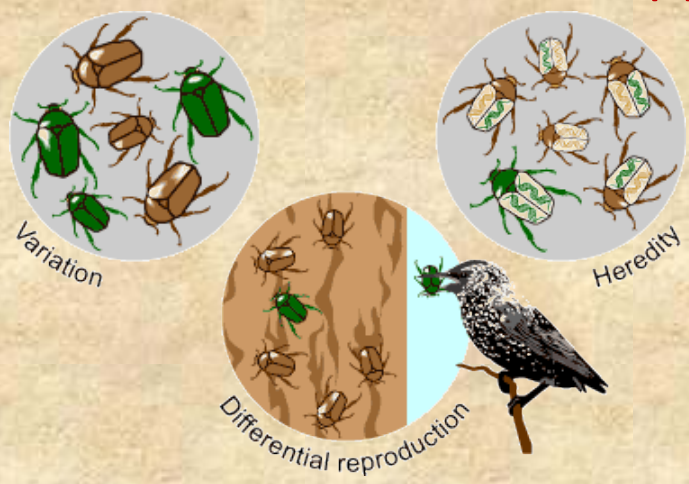
Variation Exists in Populations
Individual Differences are Inherited

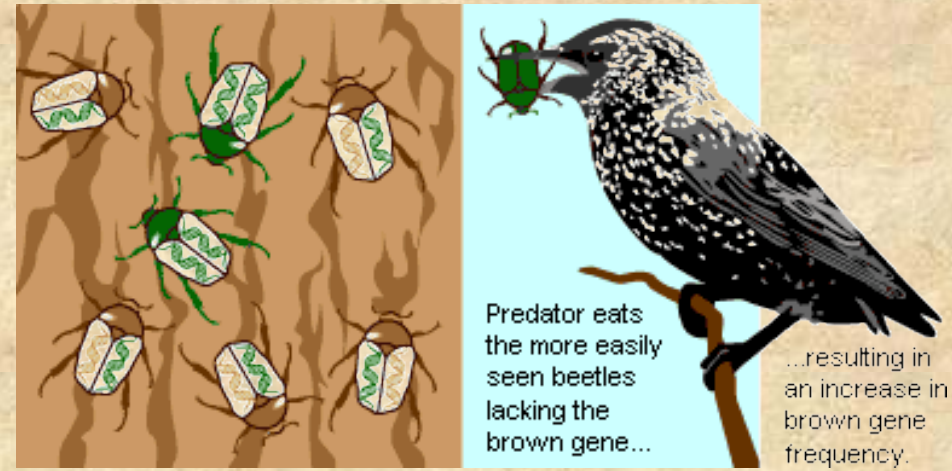
English Trumpeter

Cropper

Natural Selection

- There members of a population have heritable variation. (Variation that can be passed to offspring) – Animal breeders
- More individuals are born each generation than will survive and reproduce - Thomas Malthus ("J"-Shaped vs. Sigmoid Curves)
- The more adapted individuals survive and reproduce to a greater extent than those that lack the adaptations – Galapagos Finches
- Across generations a larger proportion of the population becomes adapted to the environment - Charles Lyell gives a time frame for this to happen





Alfred Russel Wallace – Sent an essay to Darwin from Malaysia – Summarized a theory of evolution by natural selection

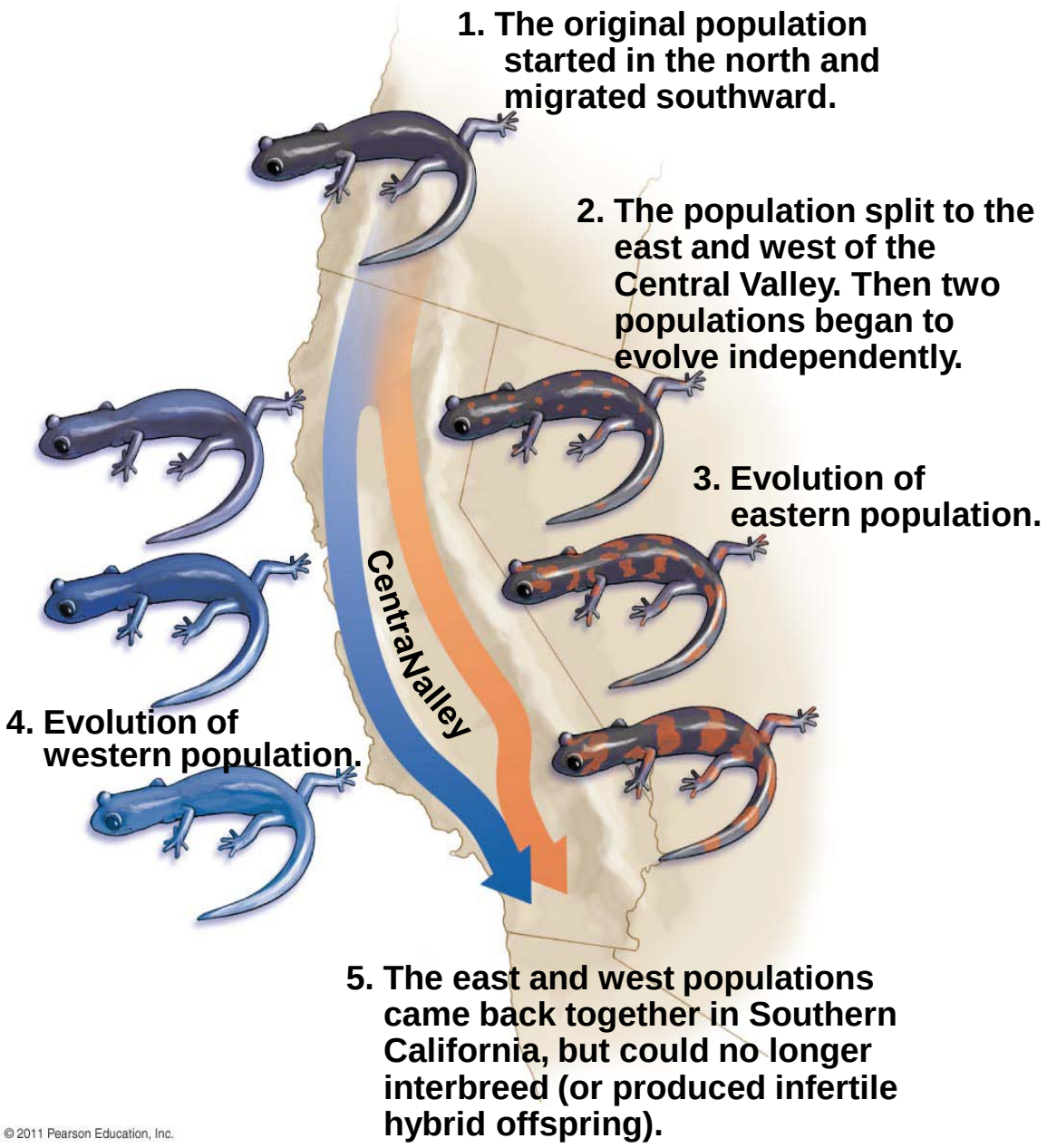
Evolution

A change in genetically based phenotypes in a population over successive generations.

Phenotype

- A physical characteristic (what you see) of an organism

Phenotypes are controlled by one or many genes

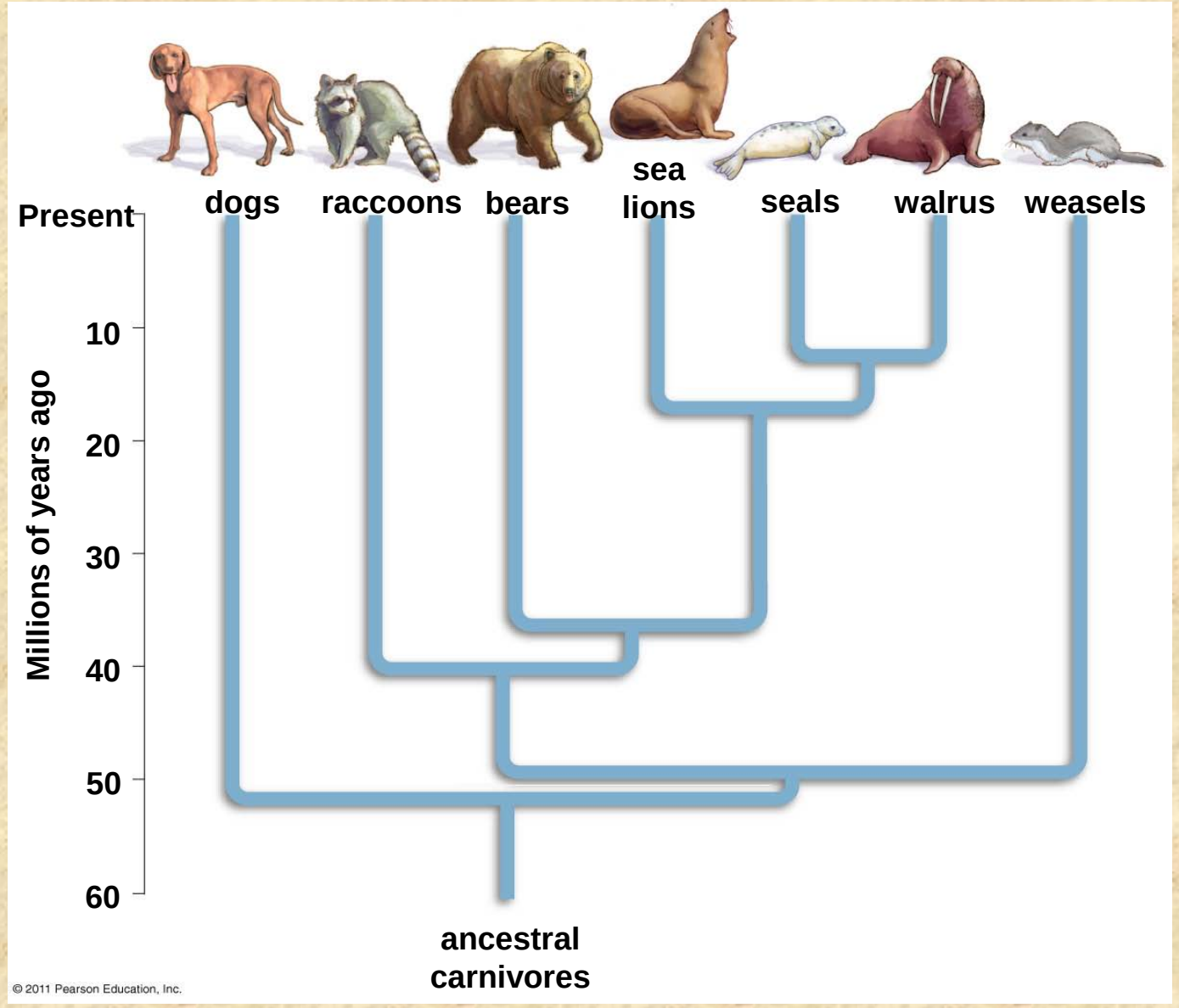


Alleles

- A distinct version of a gene that creates a distinct phenotype
- The alleles that an individual organism possesses makes up the organisms genotype.
- The alleles of the organisms population make up the gene pool for that population.
- Population: All the members of a species that live in a defined geographical region at a given time.

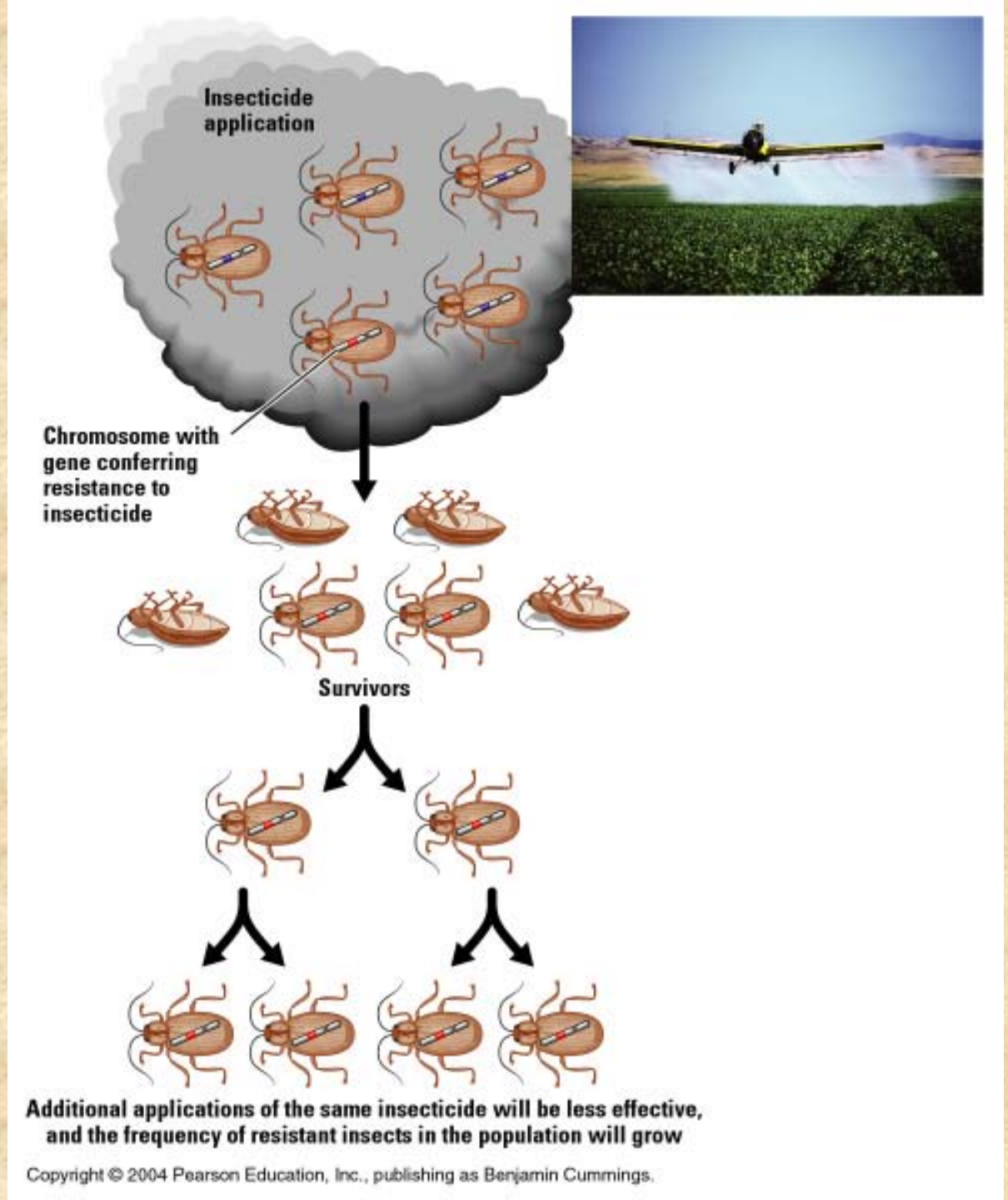
Microevolution vs. Macroevolution

- Macroevolution: evolution that leads to new species.



Microevolution

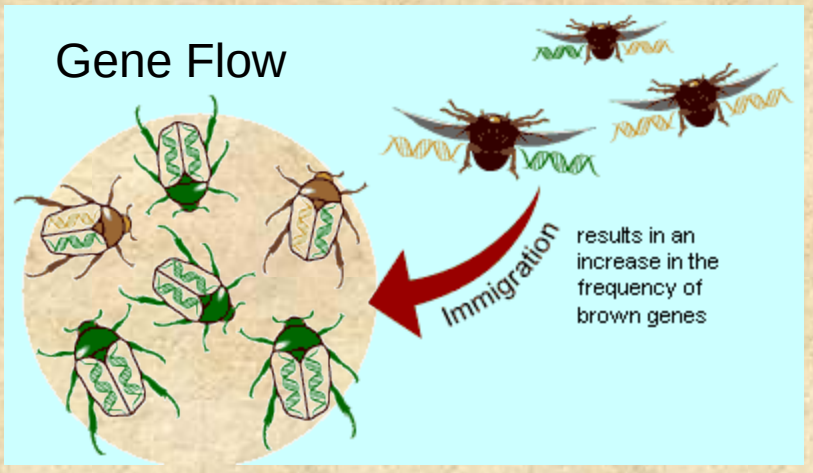
Changes in Gene (Allele) Frequencies over time



How Do Changes in Gene Frequencies Occur?

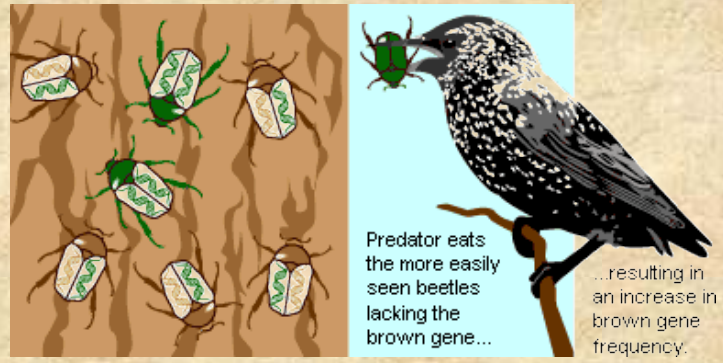
- Mutation

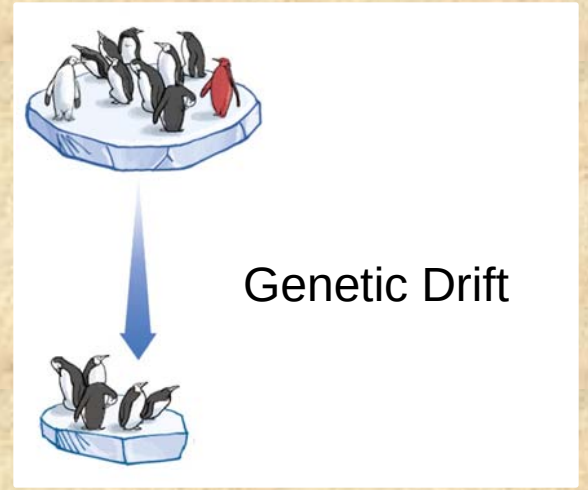
- Gene Flow

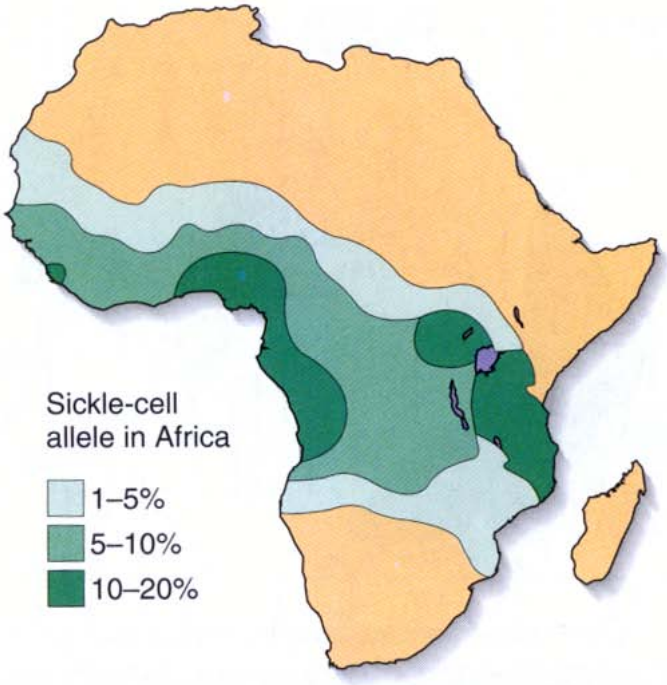


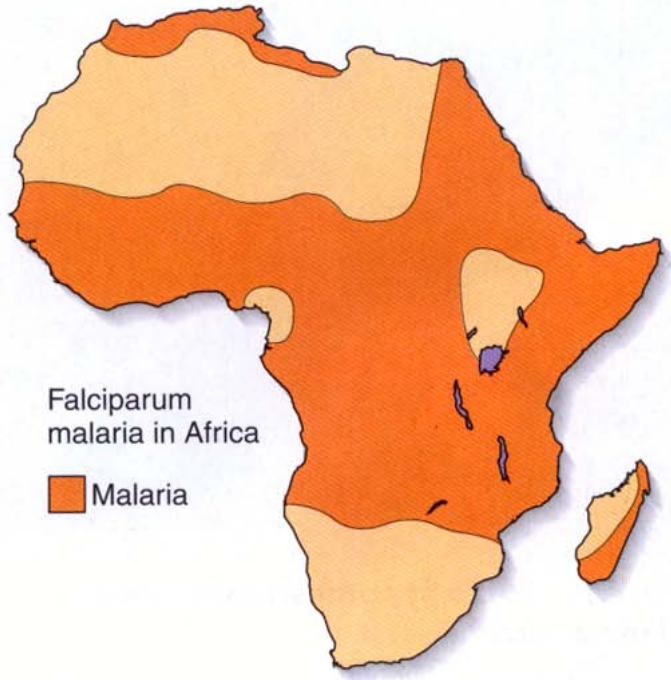
- Genetic Drift

- Selection









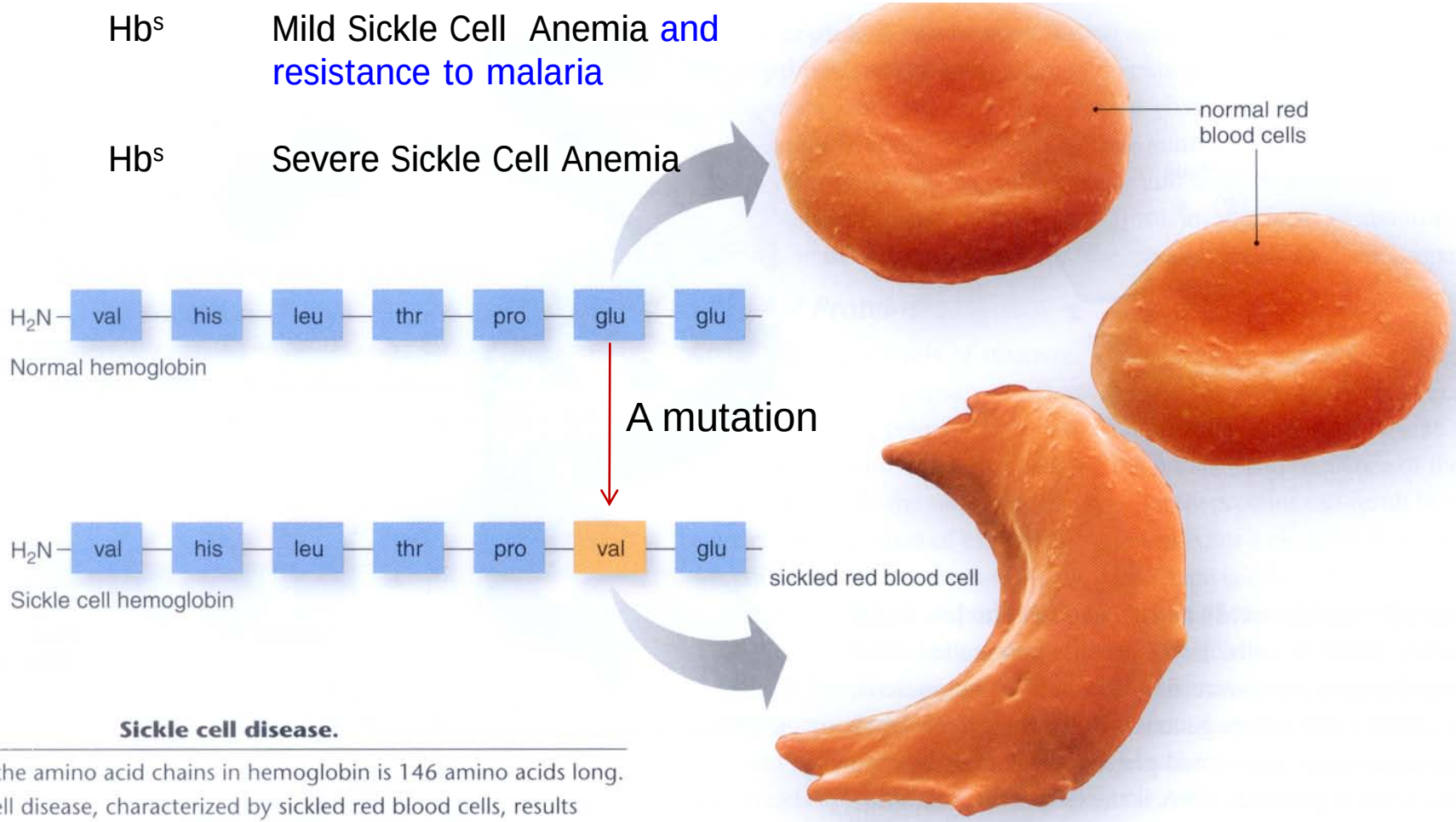
Mutation

Sickle Cell Anemia and Malaria

Mom	Dad	
Hb	Hb	Normal Hemoglobin Selected against since these individuals are susceptible to malaria (Malaria kills many people in Africa)
Hb	Hb^s	Mild Sickle Cell Anemia and resistance to malaria
Hb^s	Hb^s	Severe Sickle Cell Anemia Individuals dies early

Proteins: The Primary Structure

Mom	Dad	
Hb	Hb	Normal Hemoglobin
Hb	Hb^s	Mild Sickle Cell Anemia and resistance to malaria
Hb^s	Hb^s	Severe Sickle Cell Anemia



Sickle cell disease.

One of the amino acid chains in hemoglobin is 146 amino acids long. Sickle cell disease, characterized by sickled red blood cells, results when valine occurs instead of glutamate at the sixth amino acid.

Gene Flow

THE MIGRATION OF ANATOMICALLY MODERN HUMANS

Evidence from fossils, ancient artefacts and genetic analyses combine to tell a compelling story

Oued Djebbana (Algeria) Shell beads >35k

Peştera cu Oase (Romania) ~40k

Skhul and Qafzeh (Israel) 120-90k Shell beads ~110k

ATLANTIC CROSSING

'Lagar Velho boy' (Portugal) ~25k

40k

Tianyuan (China) ~40k

BERINGA ROUTE

16k

PACIFIC COASTAL ROUTE

Wally's Beach (US) Human occupation ~13k

PACIFIC COASTAL ROUTE

ATLANTIC CROSSING

Arlington Springs (US) Leg bone ~13k

Cactus Hill (US) Small blades 20-17k

Taforalt (Morocco) Shell beads ~82k

NORTHERN ROUTE

60k

50k

SOUTHERN ROUTE

Herto (Ethiopia) ~160k

South-east of Puebla (Mexico) Ancient footprints ~38k (contested)

BAB EL-MANDEB STRAIT

Omo Kibish (Ethiopia) ~195k

Singa (Sudan) ~155k

65k

Niah Caves (Sarawak) ~45k

Flow of genes around globe
Routes of migration
Alternative/contested routes
~13k Anatomically modern humans
10k 10,000 years ago

Fa Hien Cave and Batadomba Lena Cave (Sri Lanka) Bones and artifacts ~35k

Blombos Caves (South Africa) 75-65k 2 pieces of engraved ochre ~77k Shell beads ~75k

Klasies River (South Africa) 90-65k Cultural artifacts ~70k

Lake Mungo (Australia) ~46k

50k

Quebrada Jaguay (Peru) Human settlement ~13k

PACIFIC CROSSING

15k

Monte Verde (Chile) Flake tools and stone points ~15k

Two routes jump out as prime candidates for the human exodus out of Africa. A northern route would have taken our ancestors from their base in eastern sub-Saharan Africa across the Sahara desert, then through Sinai and into the Levant. An alternative southern route may have charted a path from Djibouti or Eritrea in the Horn of Africa across the Bab el-Mandeb strait and into Yemen and around the Arabian peninsula. The plausibility of these two routes as gateways out of Africa has been studied as part of the UK's Natural Environment Research Council's programme "Environmental Factors in the Chronology of Human Evolution & Dispersal" (EFCHED).

During the last ice age, from about 80,000 to 11,000 years ago, sea levels dropped as the ice sheets grew, exposing large swathes of land now submerged under water and connecting regions now separated by the sea. By reconstructing ancient shorelines, the EFCHED team found that the Bab el-Mandeb strait, now around 30 kilometres wide and one of the world's busiest shipping lanes, was then a narrow, shallow channel.

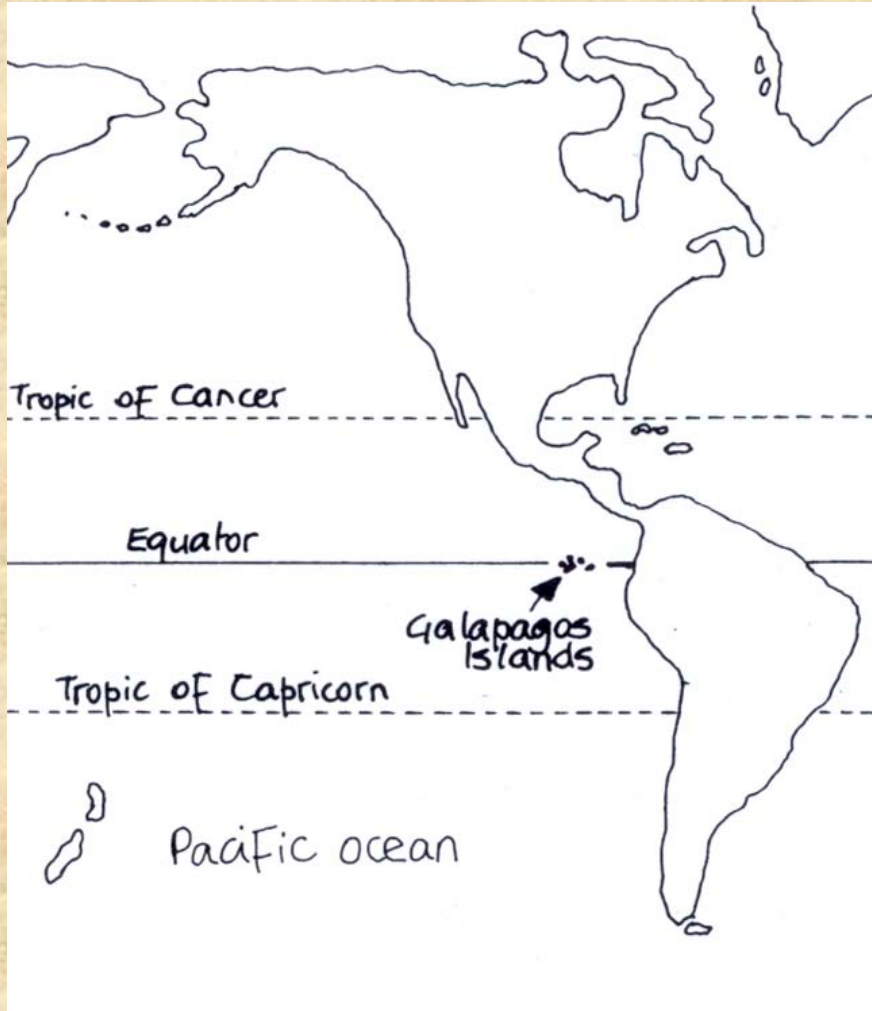
Early humans may have taken this southern route out of Africa. The northern route appears easier, especially given the team's finding that the Suez basin was dry during the last ice age. But crossing the Sahara desert is no small matter. EFCHED scientist Simon Armitage of the Royal Holloway University of London has found some clues as to how this might have been possible. During the past 150,000 years, North Africa has experienced abrupt switches between dry, arid conditions and a humid climate. During the longer wetter periods huge lakes existed in both Chad and Libya, which would have provided a "humid corridor" across the Sahara.

Armitage has discovered that these lakes were present around 10,000 years ago, when there is abundant evidence for human occupation of the Sahara, as well as around 115,000 years ago, when our ancestors first made forays into Israel. It is unknown whether another humid corridor appeared between about 65,000 and 50,000 years ago, the most likely time frame for the human exodus. Moreover, accumulating evidence is pointing to the southern route as the most likely jumping-off point.

Genetic Drift

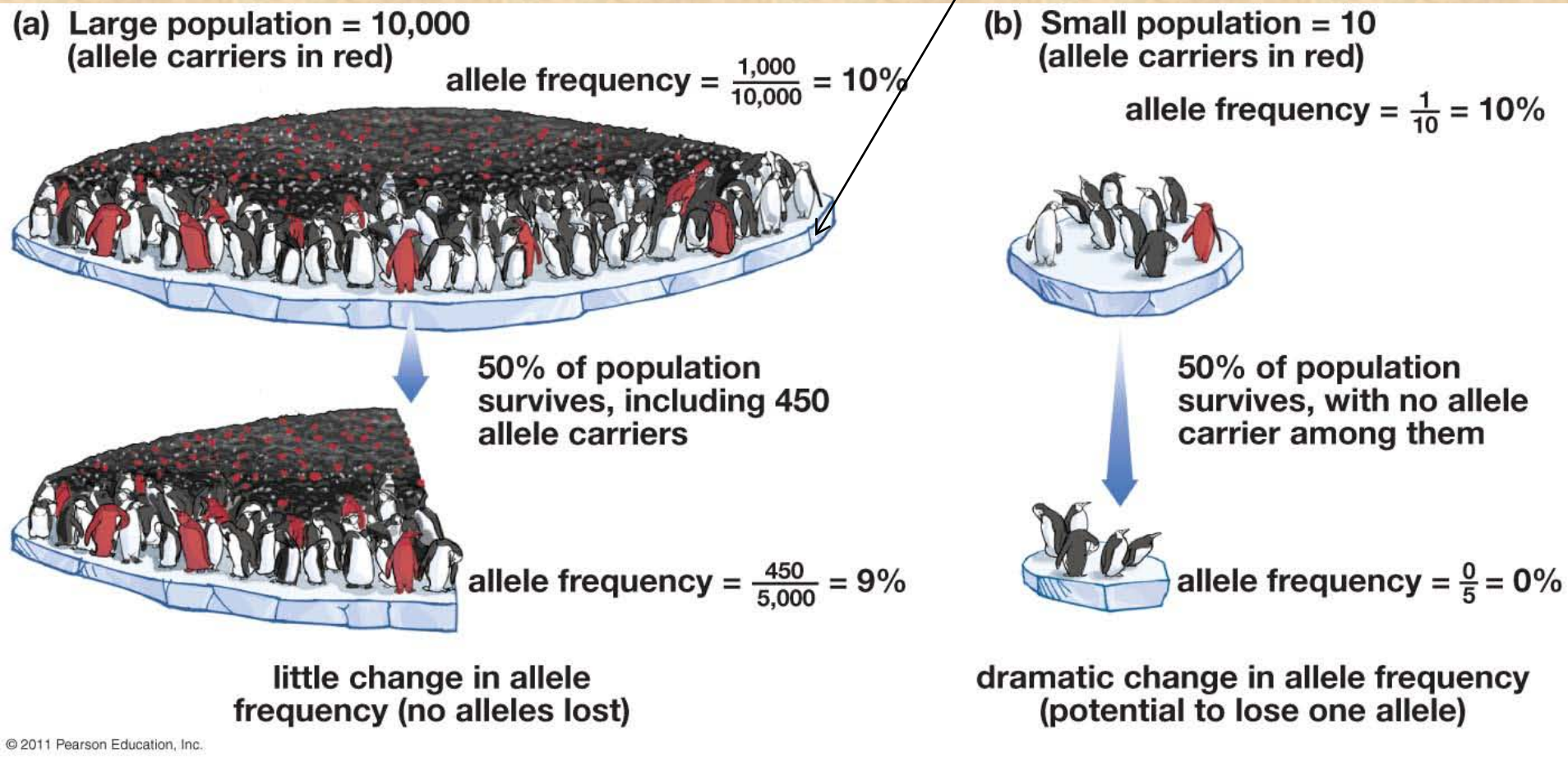
- The Chance Loss of Alleles from Small Populations

- Two Types of Genetic Drift
  - The Founder Effect
    - Islands
  - The Bottleneck Effect
    - Disease
    - Natural disasters



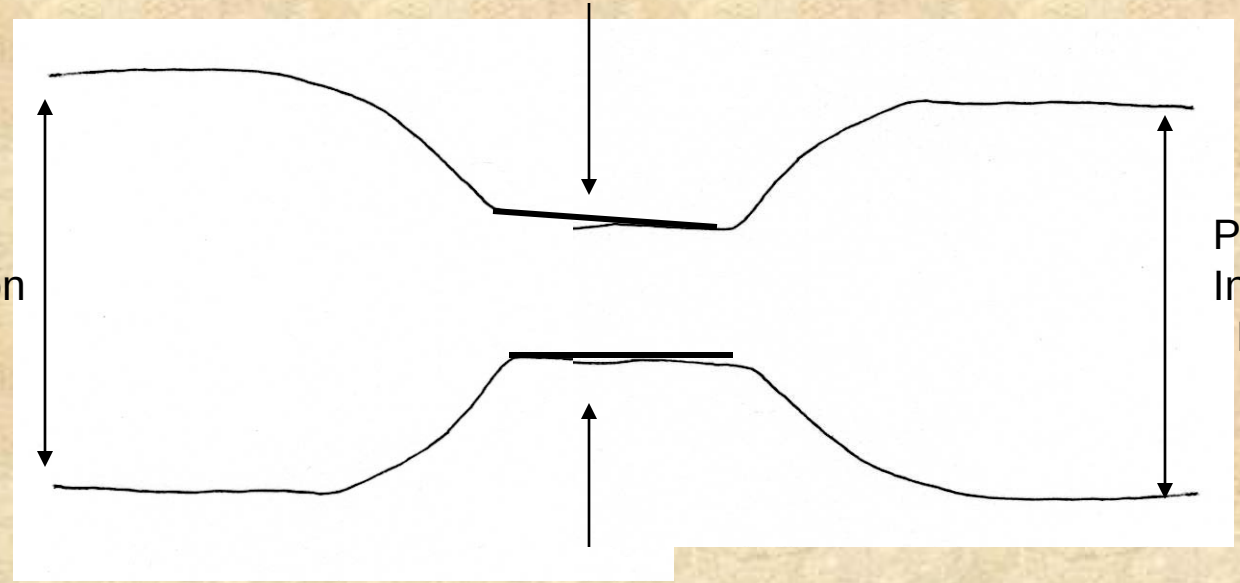
Genetic Drift

I in 10 or 10% of the Population carries the red allele



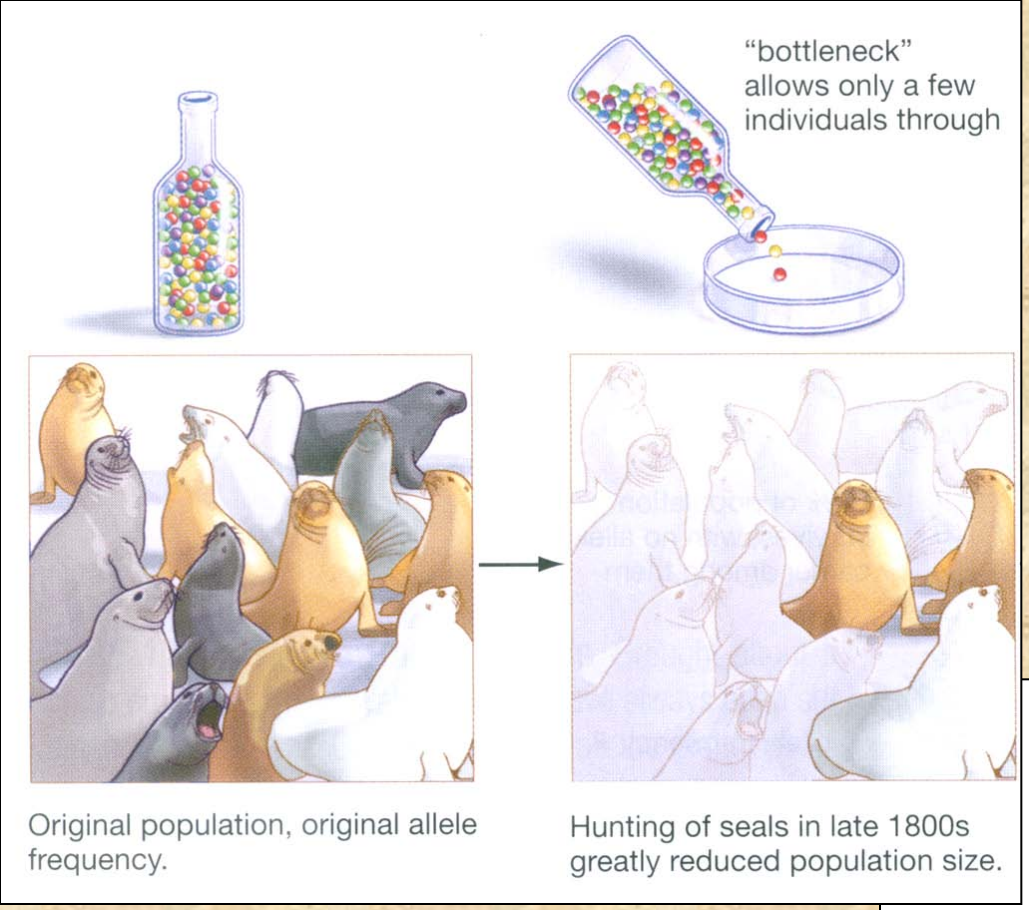
The Founder Effect: The Marine Iguana of the Galapagos Islands is Related to the Common Green Iguana of South America

Genetic Drift:
The Bottleneck Effect

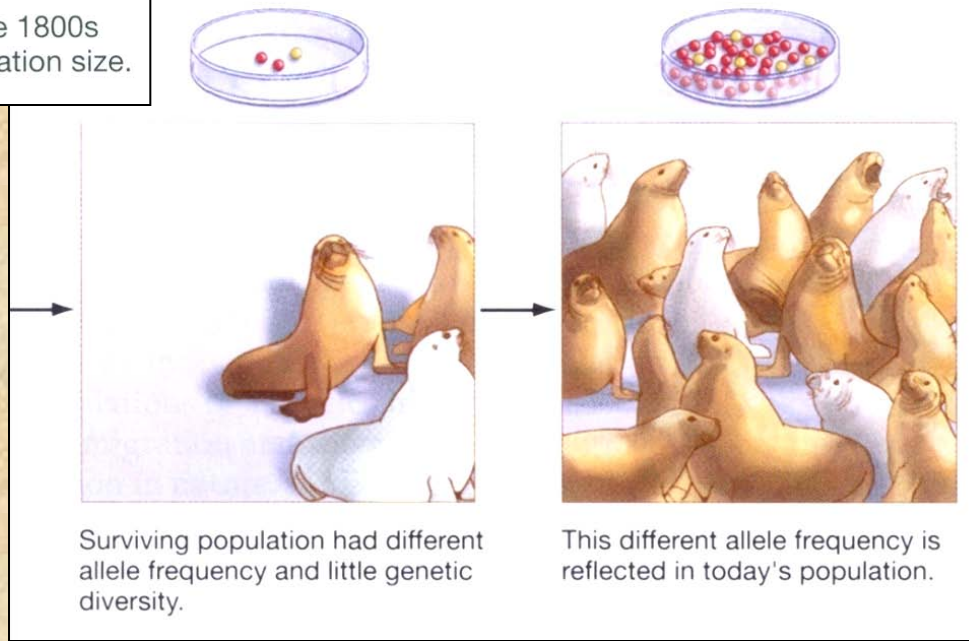


Northern Elephant Seals

- Population off California was reduced to less than 100 individuals.
- Now the population size is greater than 100,000.
- Does today's population have much genetic variability?

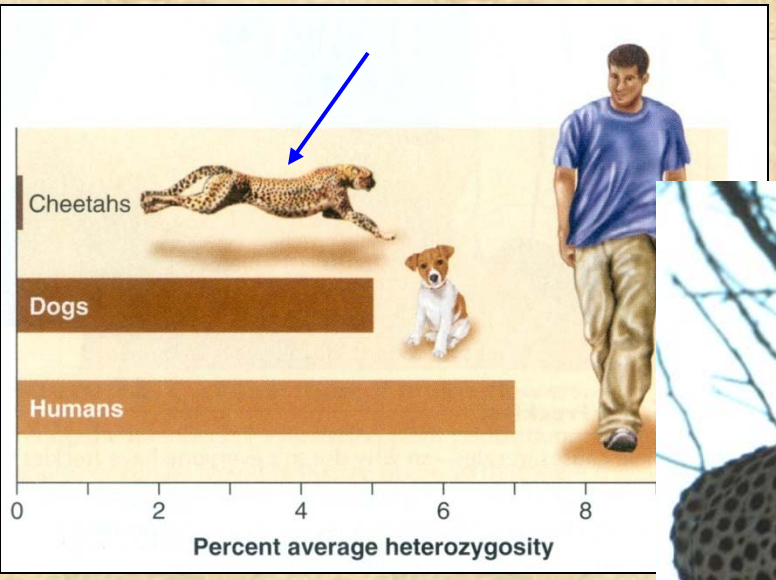


Population Bottleneck Northern Elephant Seals



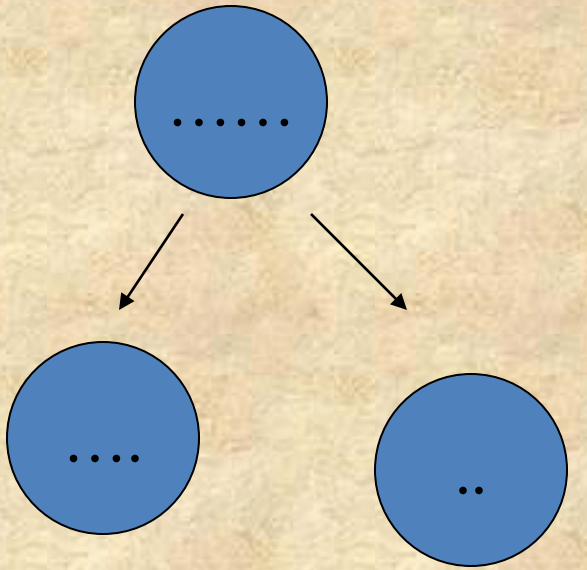
In 1910 there were less than 100 elephant seals off the coast of California

Bottlenecks Result in Loss of Heterozgosity (Loss of Genetic Diversity)



Types of Speciation

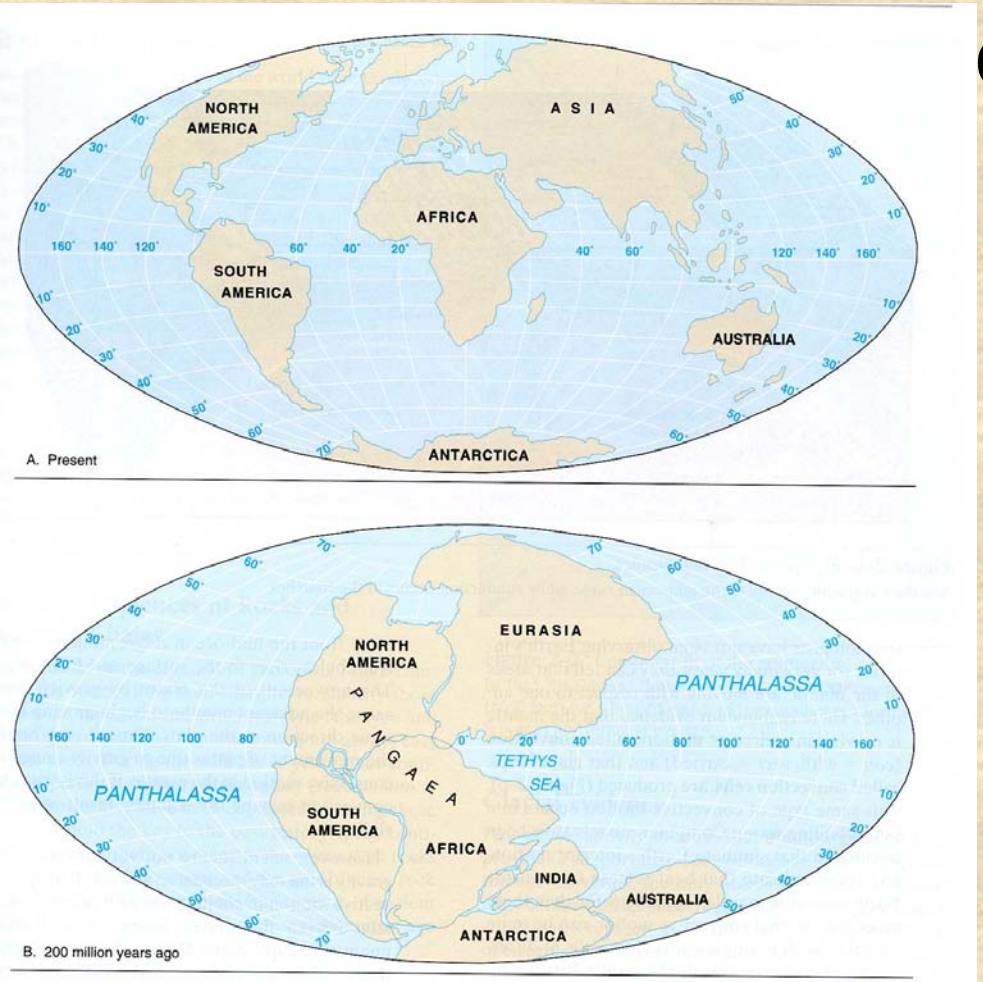
- Allopatric Speciation
  - Populations are separated



- Phase 1: Geographic Isolation
- Phase 2: Genetic Divergence
- Phase 3: Populations can no longer interbreed

Allopatric Speciation

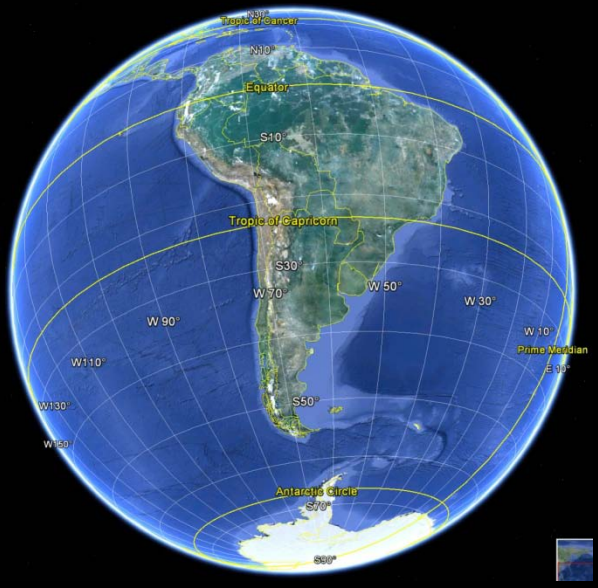
Populations are separated by geologic or climatic events

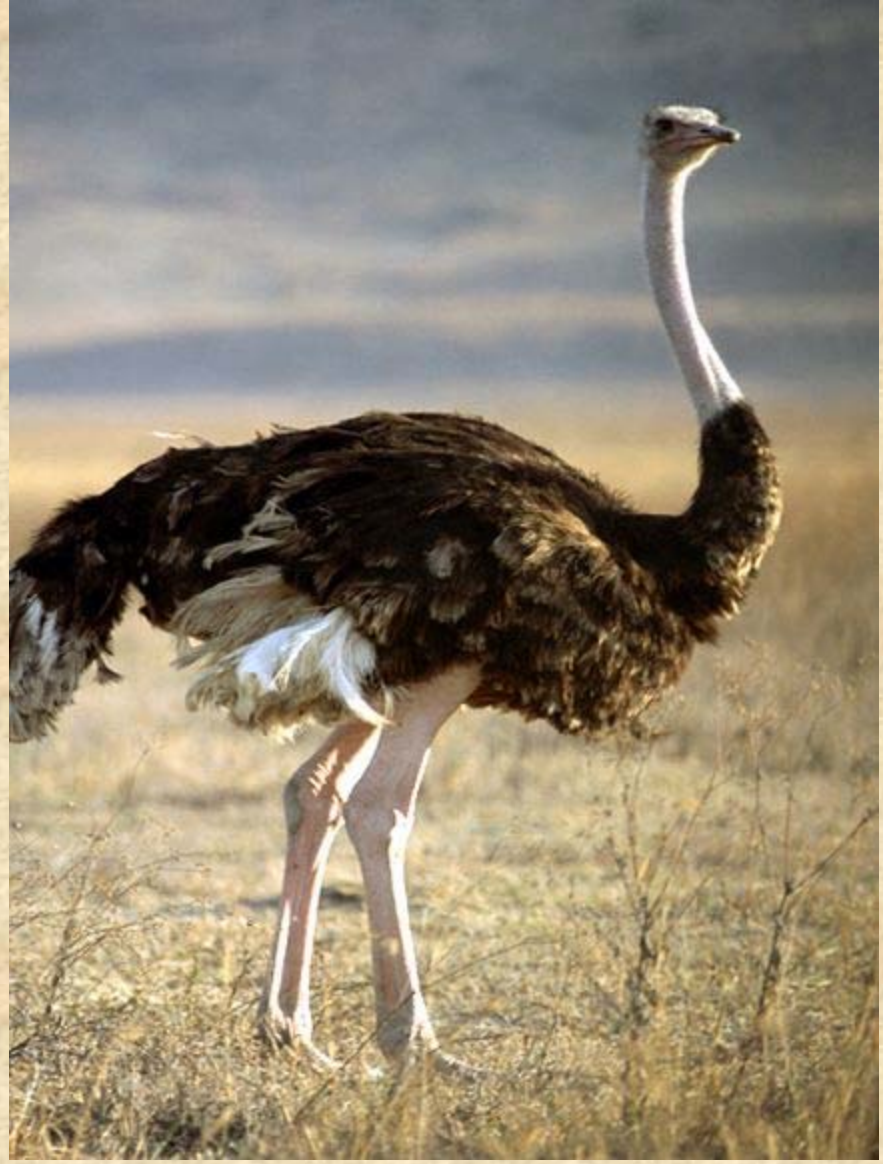


Continental Drift- Flightless Birds

- South America
  Rheas
- Africa
  Ostriches
- Australia
  Emus and Cassowaries

The emu of South America





Ostriches

TheEmu and Cassowary

Cassowary

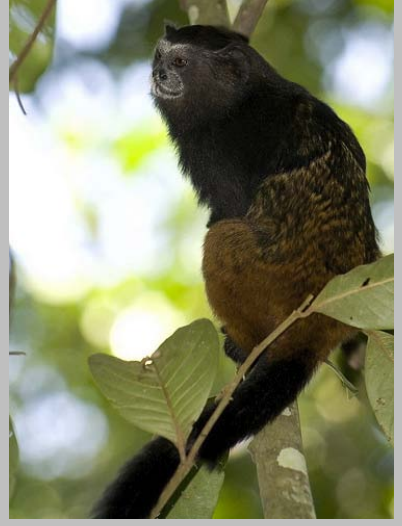
Emu

Abert's squirrel, south rim of Grand Canyon

Kaibab squirrel, north rim of Grand Canyon

Allopatric Speciation

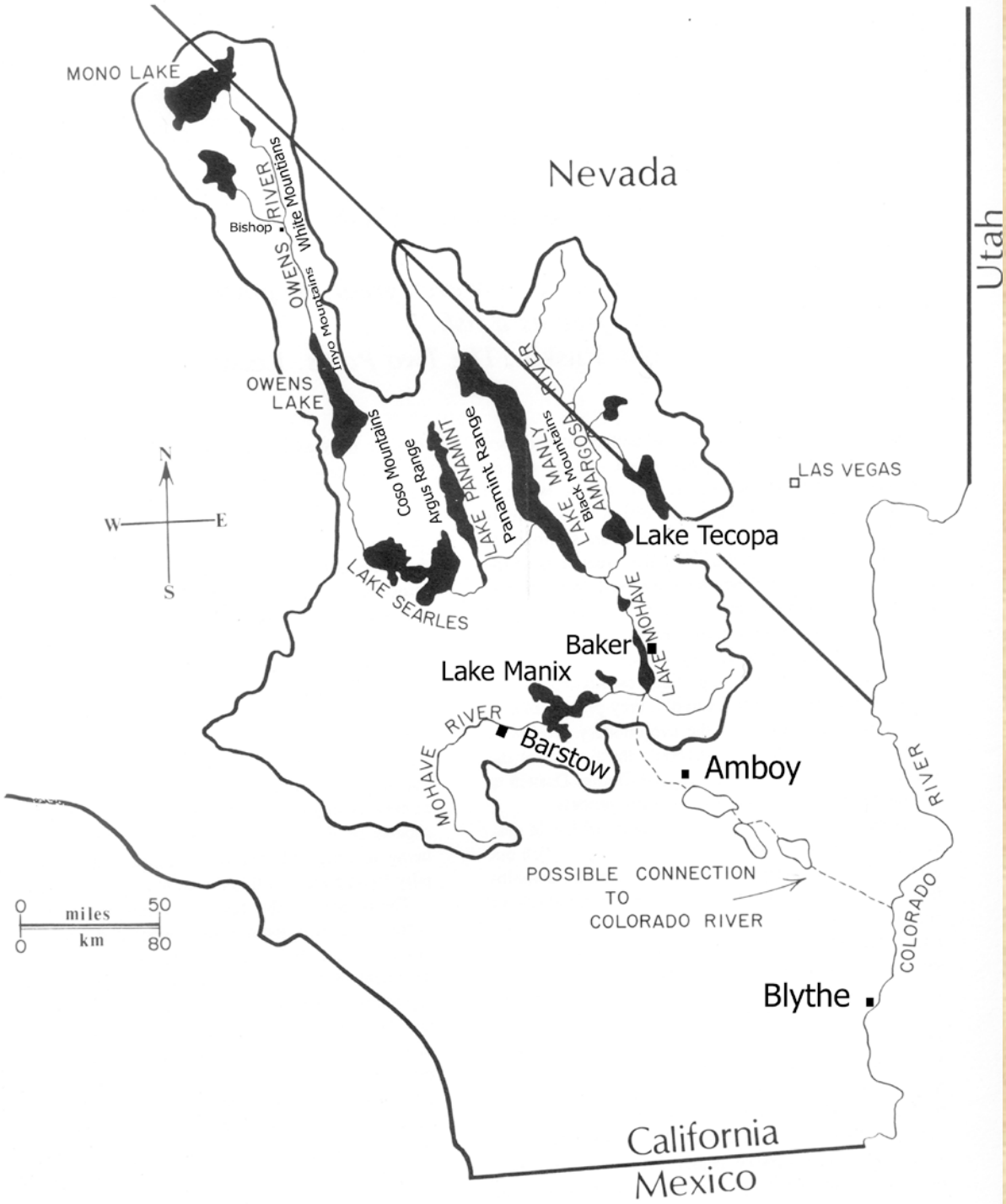
The two populations of squirrels were separated about 10,000 years ago.



Rio Jurua in western Brazil isolates populations of saddle-back tamarins.

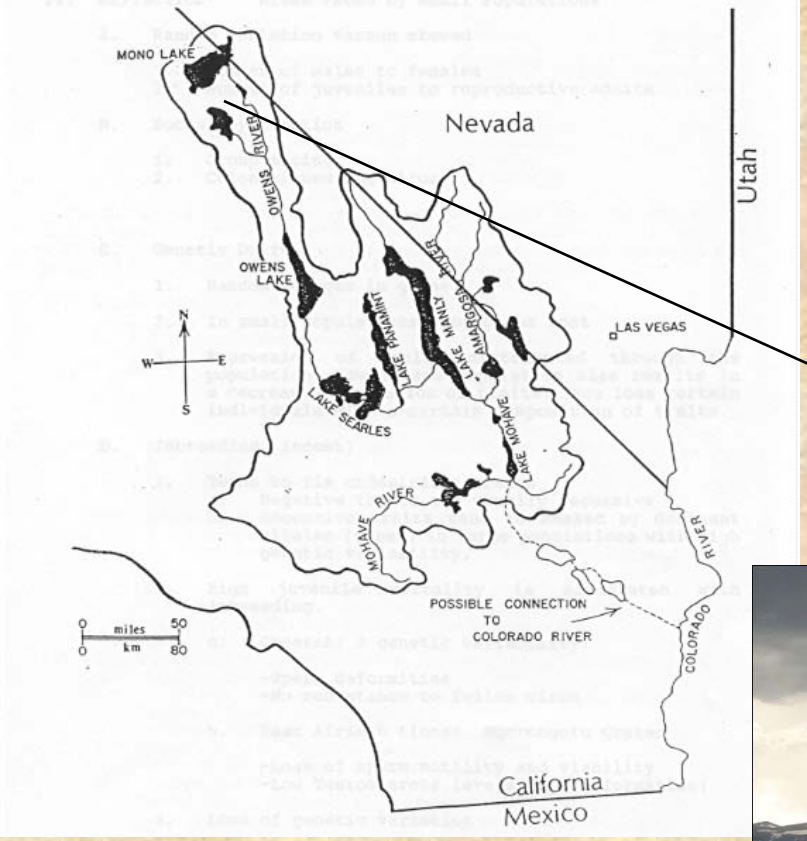
Genetic exchange does not occur where the river is the widest.

A corridor to promote genetic exchange between primates in Borneo.

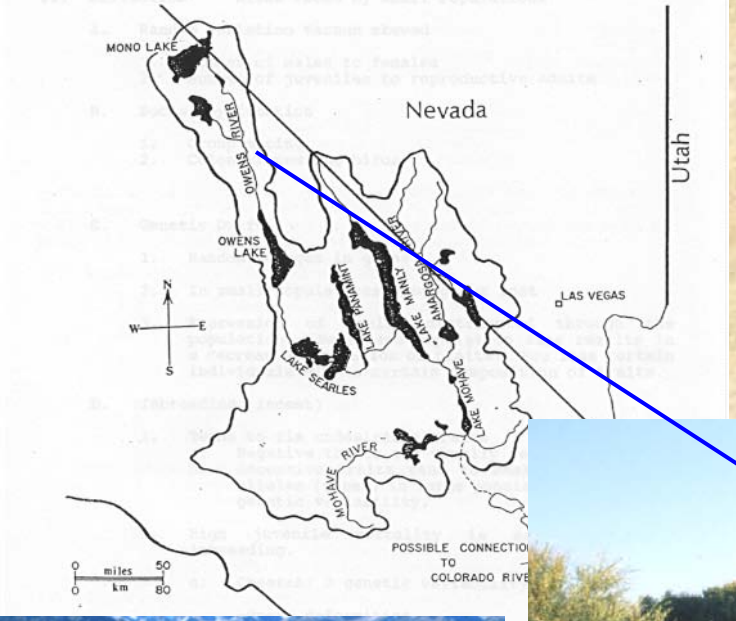


Drying of Pleistocene lakes isolated different populations of pupfish.

Populations isolated in different regions had to adapt to different habitats.


MONO LAKE
Nevada
Utah
OWENS RIVER
OWENS LAKE
LAKE PANAMINT
LAKE MANLY
AMARGOSA RIVER
LAS VEGAS
N
W
E
S
LAKE SEARLES
LAKE MOHAVE
MOJAVE RIVER
COLORADO RIVER
POSSIBLE CONNECTION
TO
COLORADO RIVER
0 miles 50
0 km 80
California
Mexico

Owens River


MONO LAKE
Nevada
Utah
OWENS RIVER
OWENS LAKE
LAS VEGAS
LAKE PANAMINT
LAKE MANLY
LAKE AMARGOSA
LAKE SEARLES
LAKE MOHAVE
MOJAVE RIVER
N
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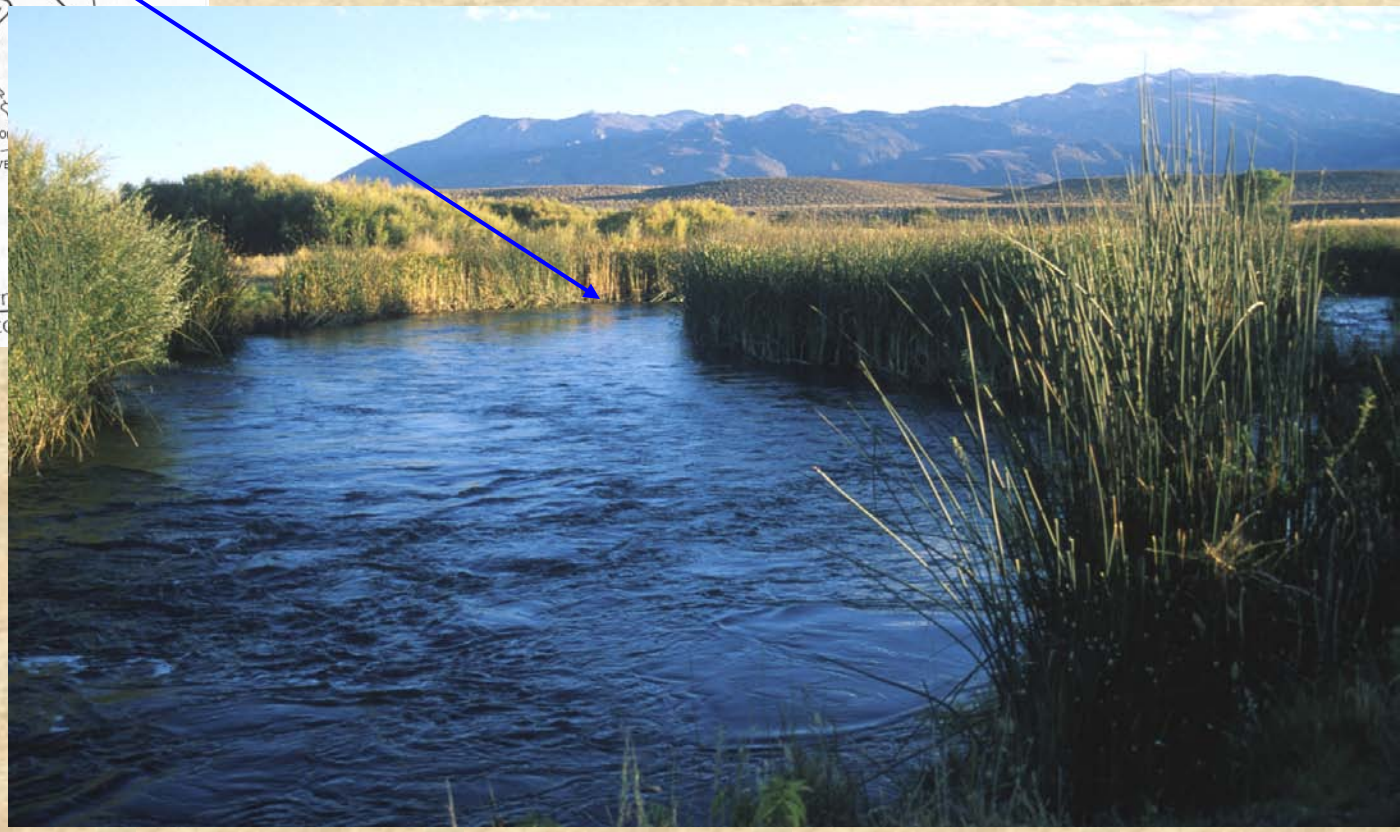
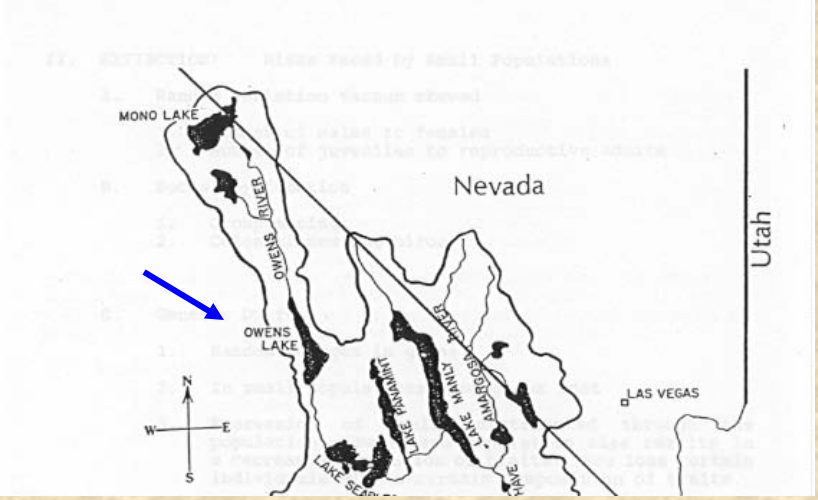
S
0 miles 50
0 km 80
POSSIBLE CONNECTIO
TO
COLORADO RIVE


CITY OF LOS ANGELES
PRIVATE PROPERTY
NO
CAMPING
ALLOWED
VIOLATORS WILL BE PROSECUTED FOR TRESPASSING - 602(1) CPC





Basin and Range Province

Death Valley

Panamint Valley

Coso Mountains

Owens Lake

Sierra Nevada


Panamint Mountains
Death Valley

Floor of Death Valley

Isolated Pupfish Populations

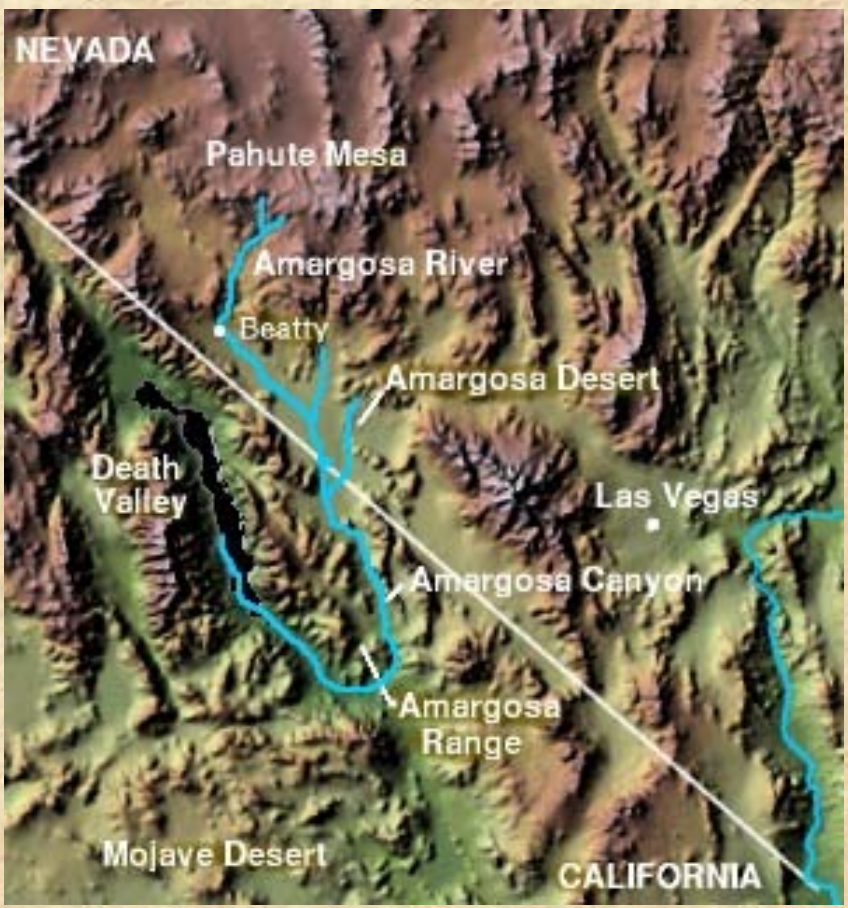
TABLE 1. Ecology and geochronology of five western pupfish species

Species	Range	Habitat ecology
C. macularius	Sonoyta and Colorado basins, including Salton Sea.	Fluctuates in temperature; variable in salinity.
C. radiosus	Fish Slough, Owens Valley.	Fluctuates in temperature; freshwater.
C. nevadensis	Amargosa basin, Death Valley. Several subsepecies.	Fluctuating and constand habitants.
C. salinus	Salt Creek, Cottonball basin, Death Valley	Fluctuates in temperature; (0-40C.) usually highly saline.
C. diabolis	Devil's Hole, Ash Meadows, Death Valley	Constant high temperature (34C.), freshwater.
C. milleri	Cottonball Marsh, Death Valley	Fluctuates in both temperature and salinity.

For details see Miller (1948), Hubbs and Miller (1948) Liu (1969)

Amargosa Pupfish: *Cyprinodon nevadesnsis*

The section of the river where it flows perennially is in the Amargosa Canyon along the southeast end of the Amargosa Range near the town of Shoshone, California. Along a 20 mi (32 km) stretch in the Amargosa Canyon it sustains a small margin of riparian wetlands in the surrounding desert. The water, as the name suggests, is non-potable by humans but is a critical source of water for the area wildlife in this section.



Saratoga Springs

The Saratoga Springs Pupfish is only found in Saratoga Springs in the south east corner of Death Valley National Park. The habitat has a spring that has a relatively constant temperature (26.6 - 29^{o}C) and its overflow forms a series of marshes and shallow lakes. This species, *Cyprinodon nevadensis nevadensis* is a subspecies of the Amargosa Pupfish, *Cyprinodon nevadensis.*

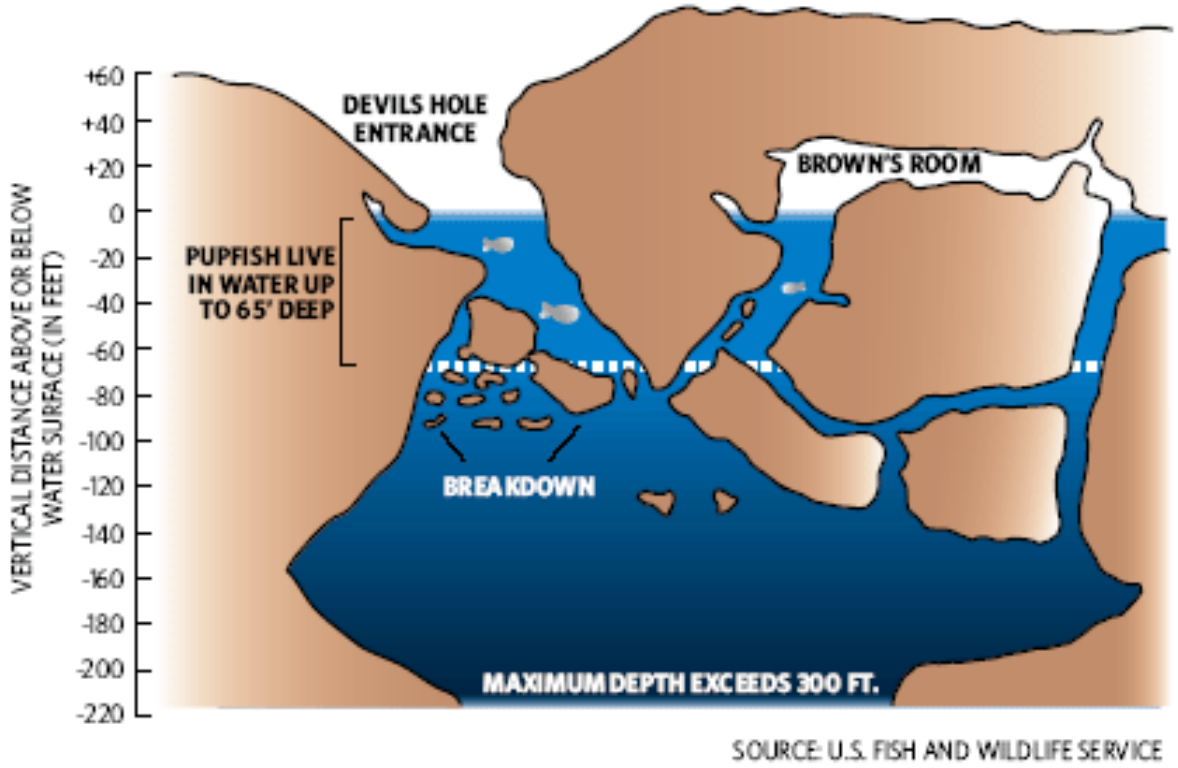
Salt Creek Pupfish

This pupfish lives only in salt creek on the floor of Death Valley.

The Devils Hole Pupfish

A watery oasis of life

The Devils Hole pupfish has adapted to live in the warm waters of the site, and depends on the unique characteristics of the cave to reproduce.



SOURCE: U.S. FISH AND WILDLIFE SERVICE

Devils Hole

Isolated Pupfish Populations

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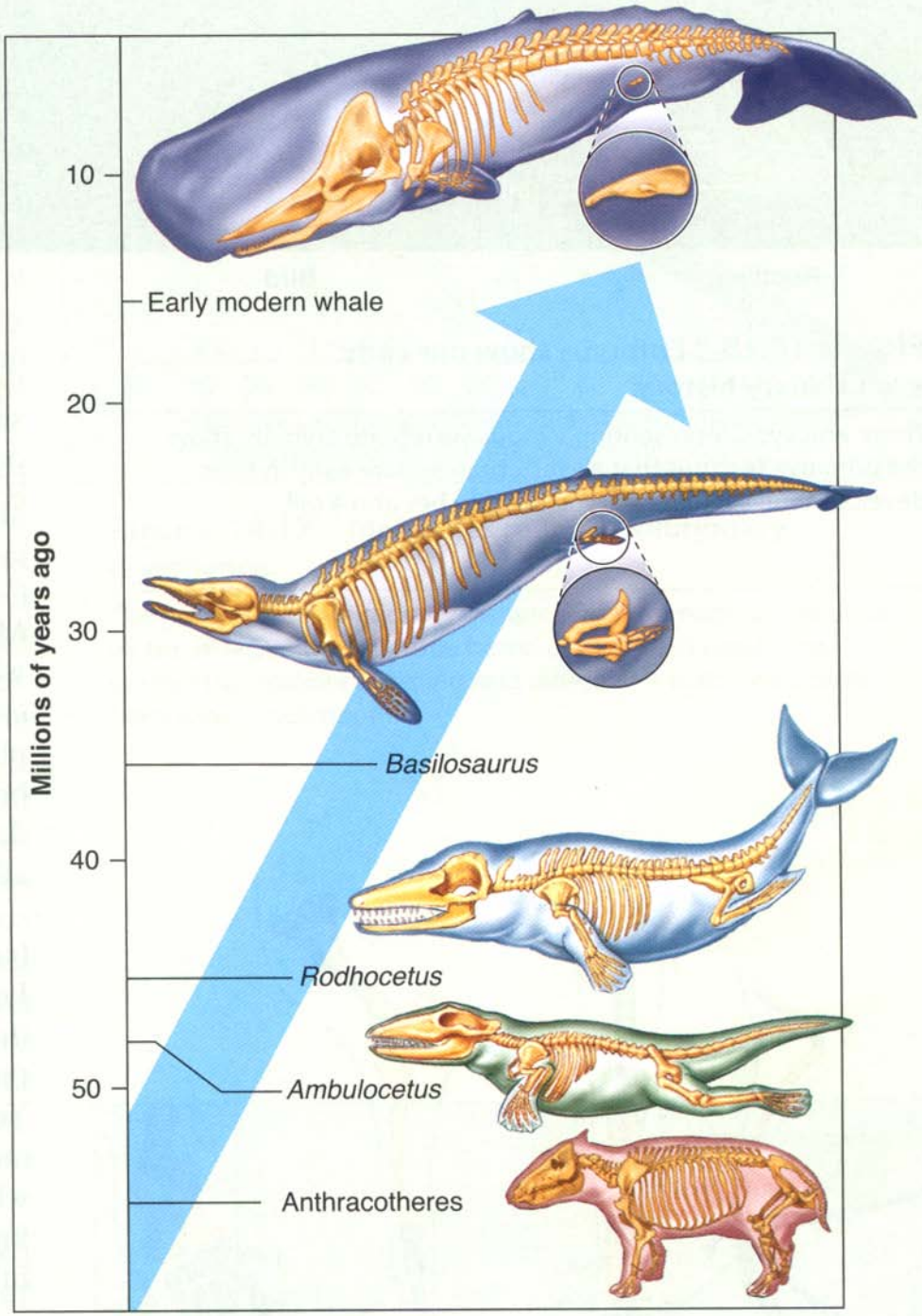
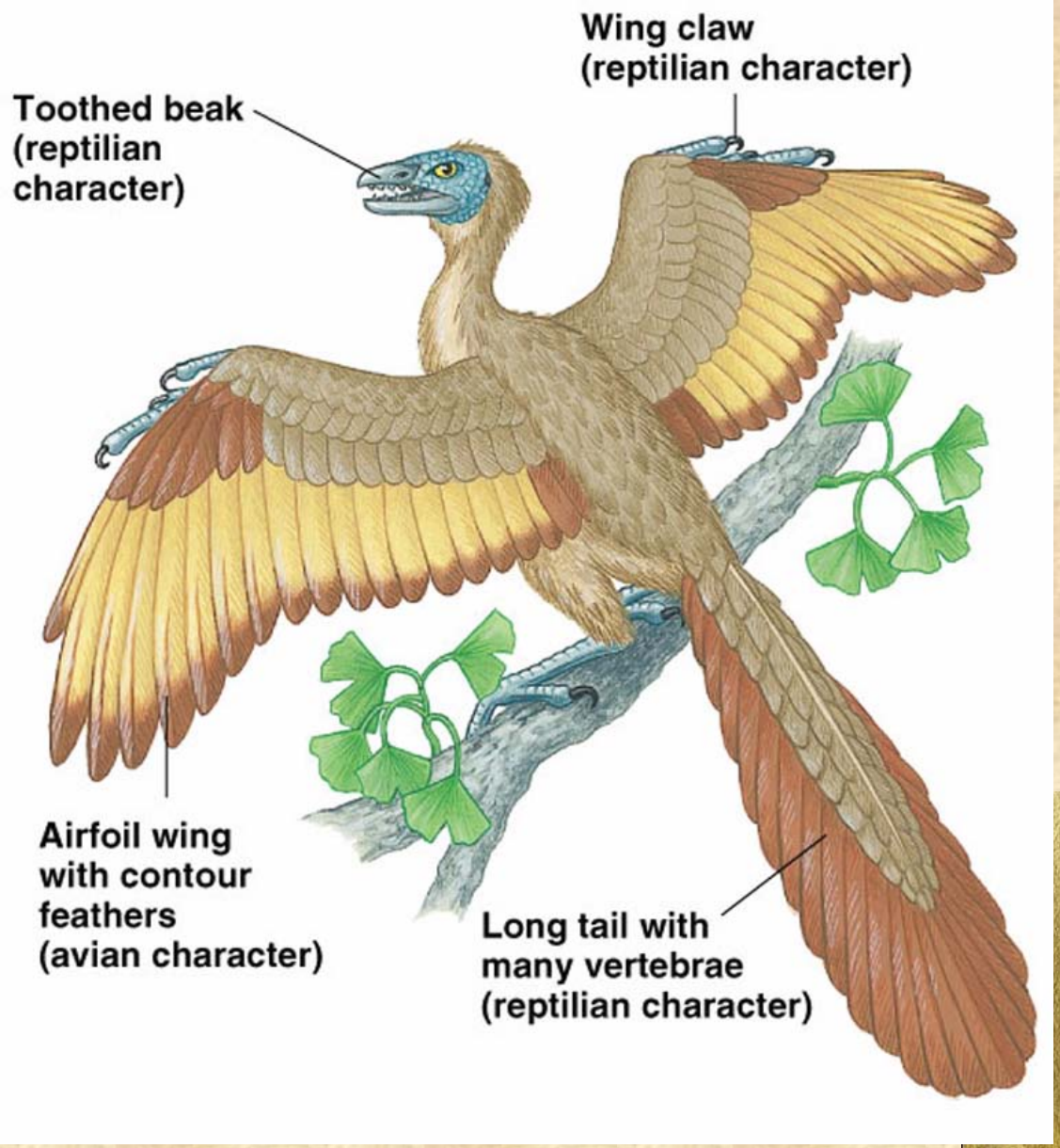
Adaptive Radiation

- Rapid evolution of mammals in the early Cenozoic
  - Empty niches left by extinction of dinosaurs
- Galapagos finches
  - Empty niches on newly formed volcanic islands

Evidence for Evolution

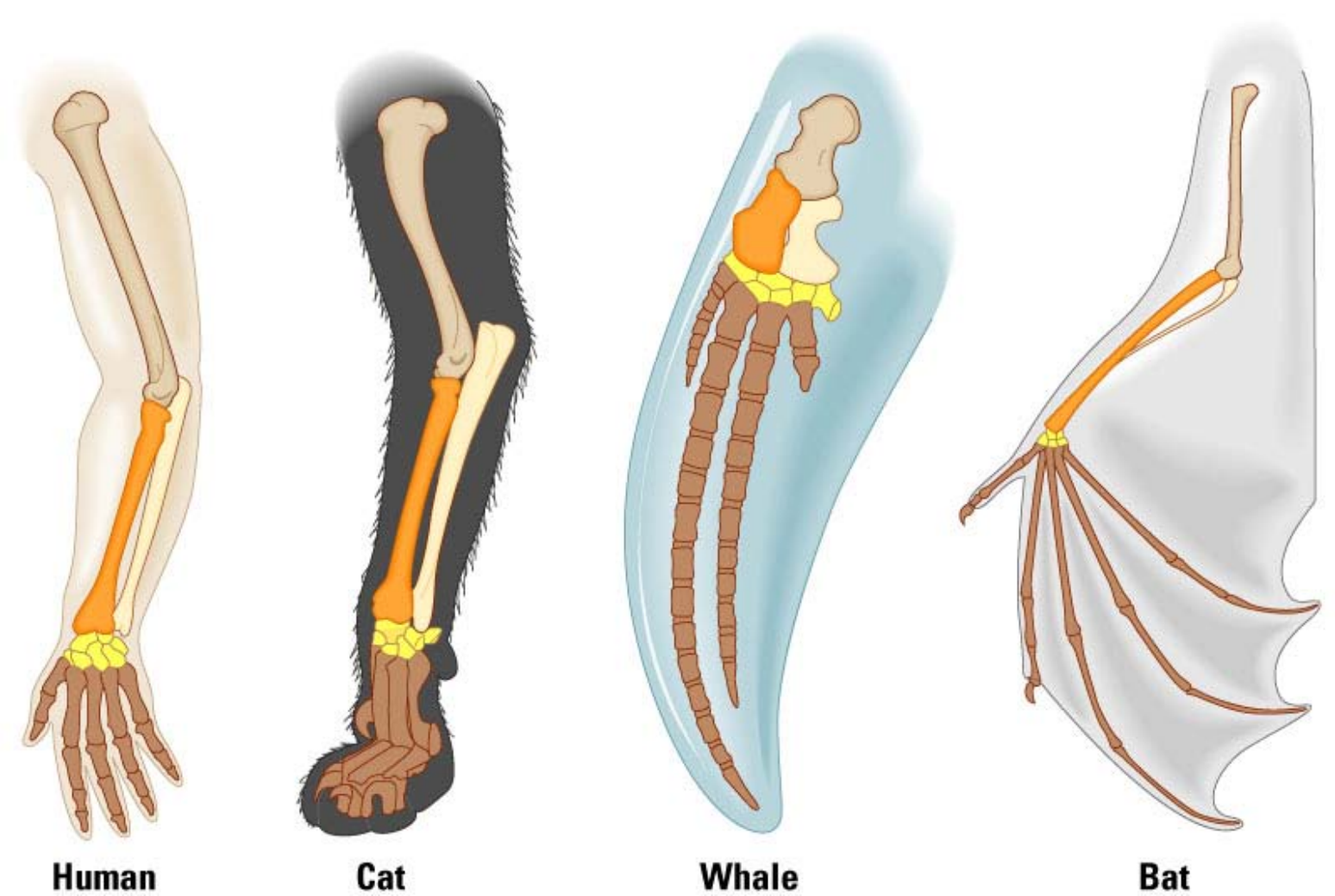


The evolution of whales is well documented in the fossil record.

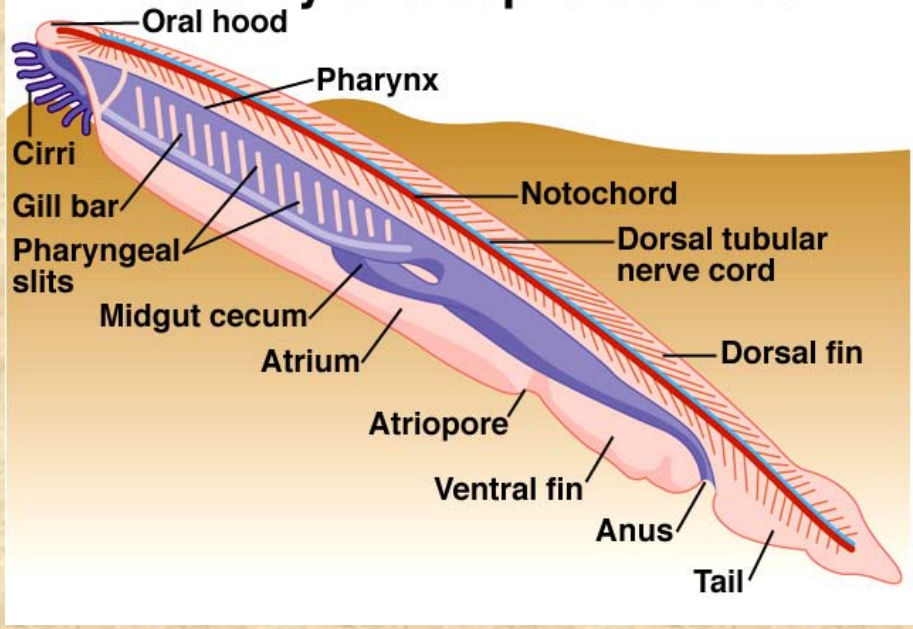


Archaeopteryx

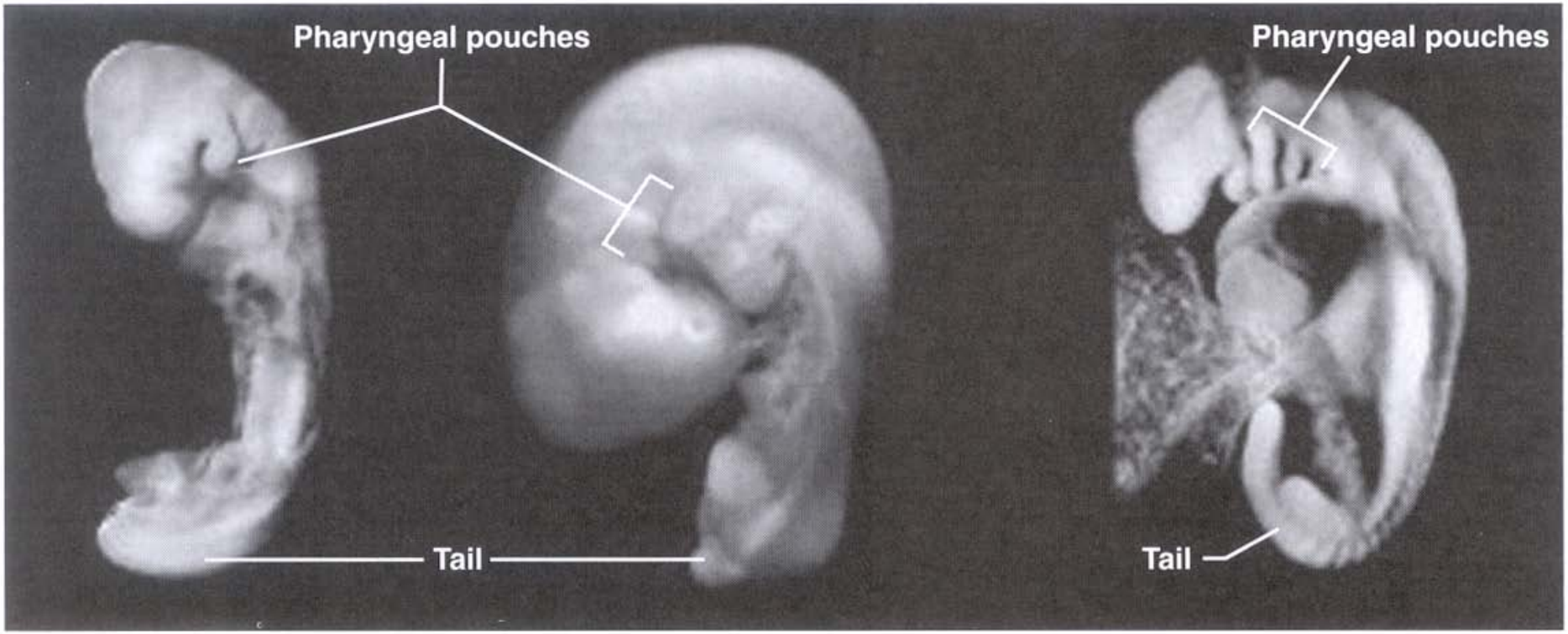
Homologous Structures



Characteristics of Chordates



- Notochord
  - Precursor to your backbone (vertebral column)
- Dorsal nerve chord
  - Anterior end becomes enlarged to form brain
- Pharyngeal gill slits
  - Evolved as filter feeding apparatus
- Postanal tail
  - Locomotion



Kingdom Animalia

Phylum Chordata

Subphylum Vertebrata

Class Reptilia - Reptiles

Class Aves – Birds

Class Mammalia – Mammals

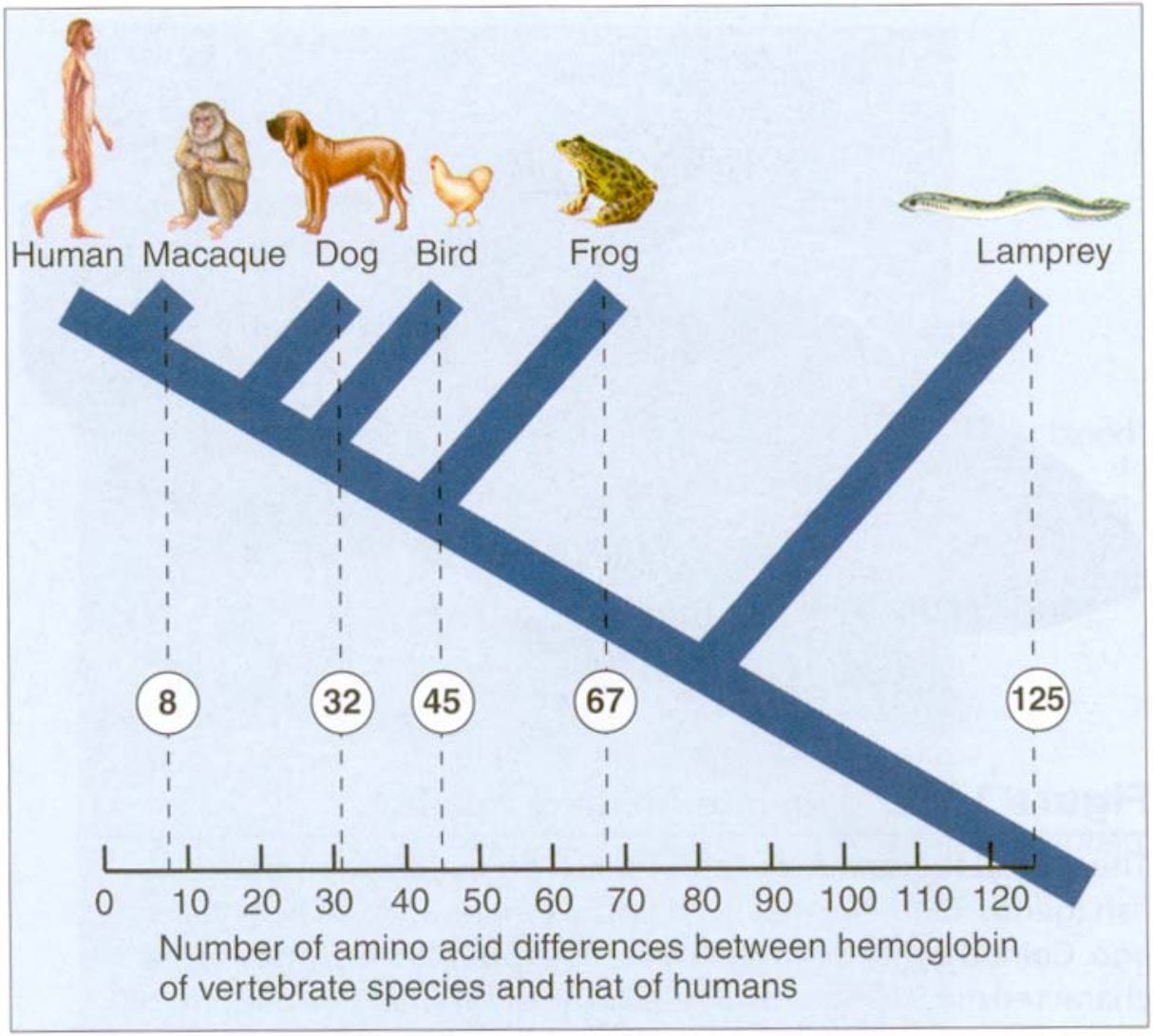
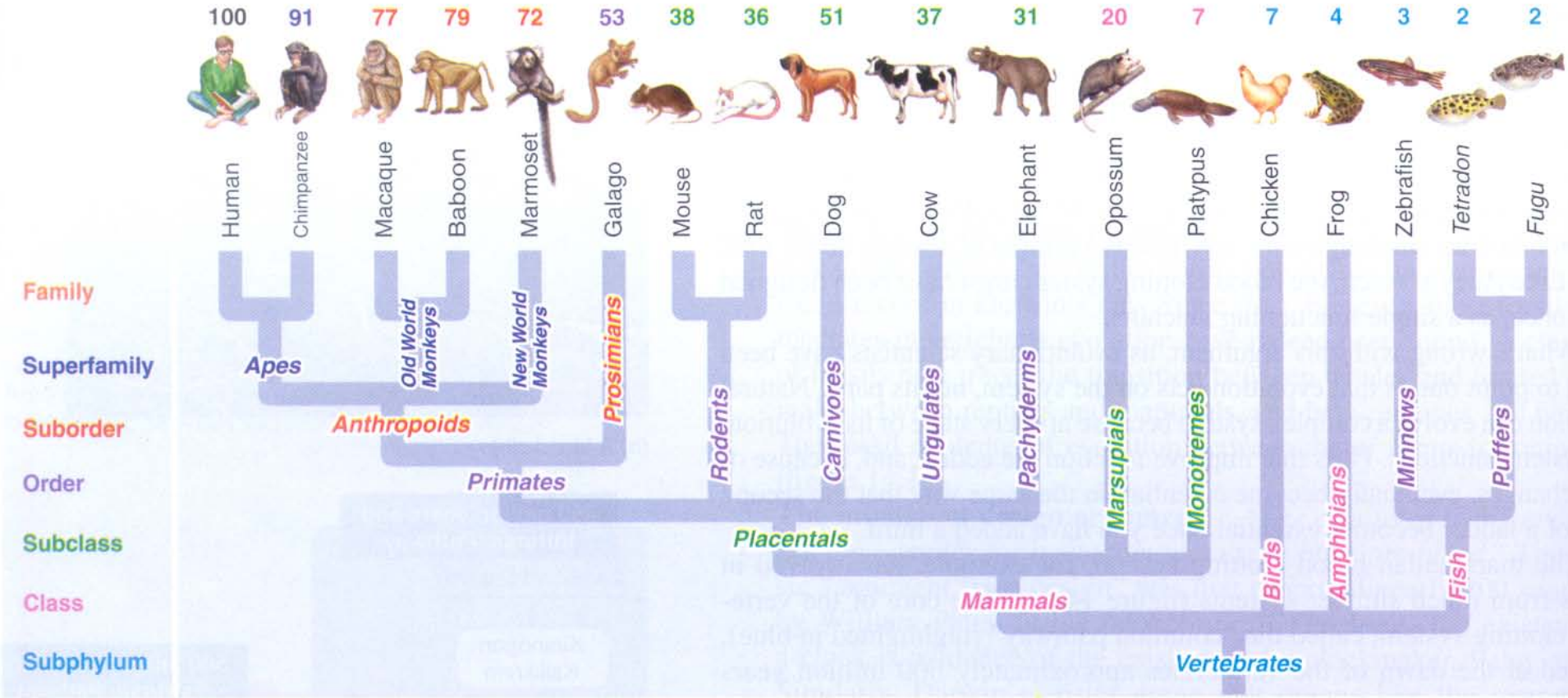


Figure 14.17 **Molecules reflect evolutionary divergence.**

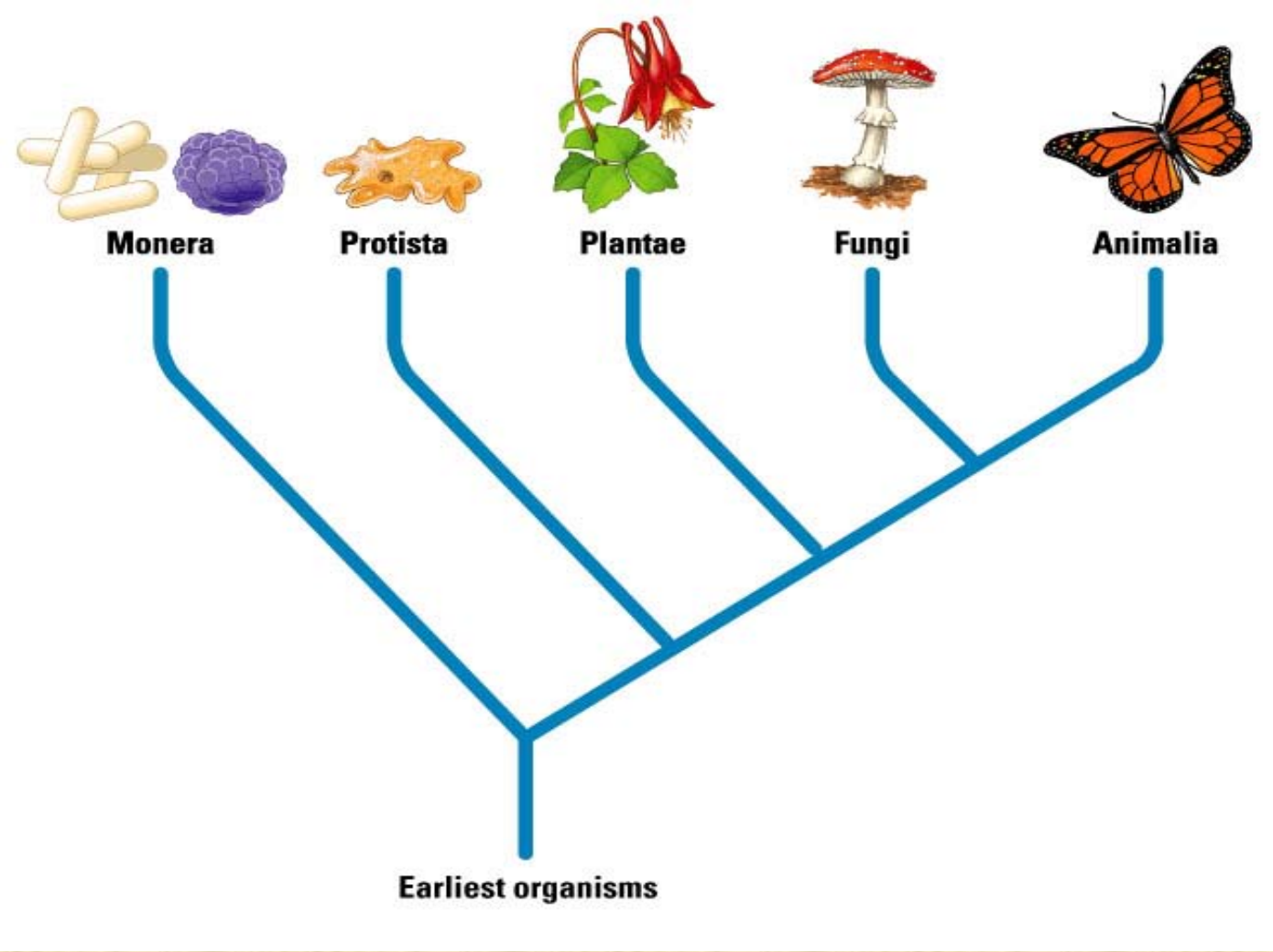
The greater the evolutionary distance from humans (as revealed by the *blue* evolutionary tree based on the fossil record), the greater the number of amino acid differences in the vertebrate hemoglobin polypeptide.

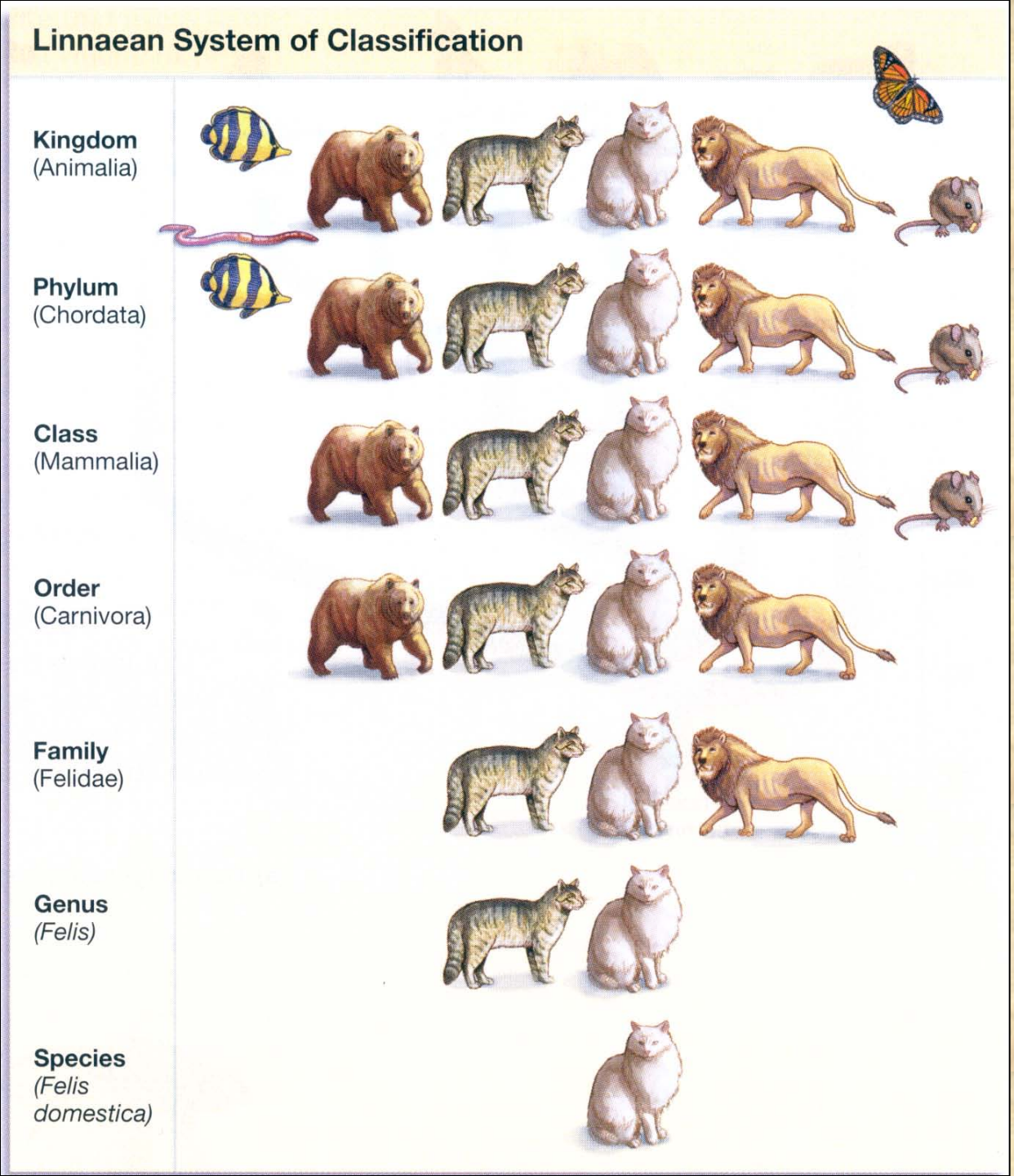


Genomic similarity reflects evolutionary relatedness.

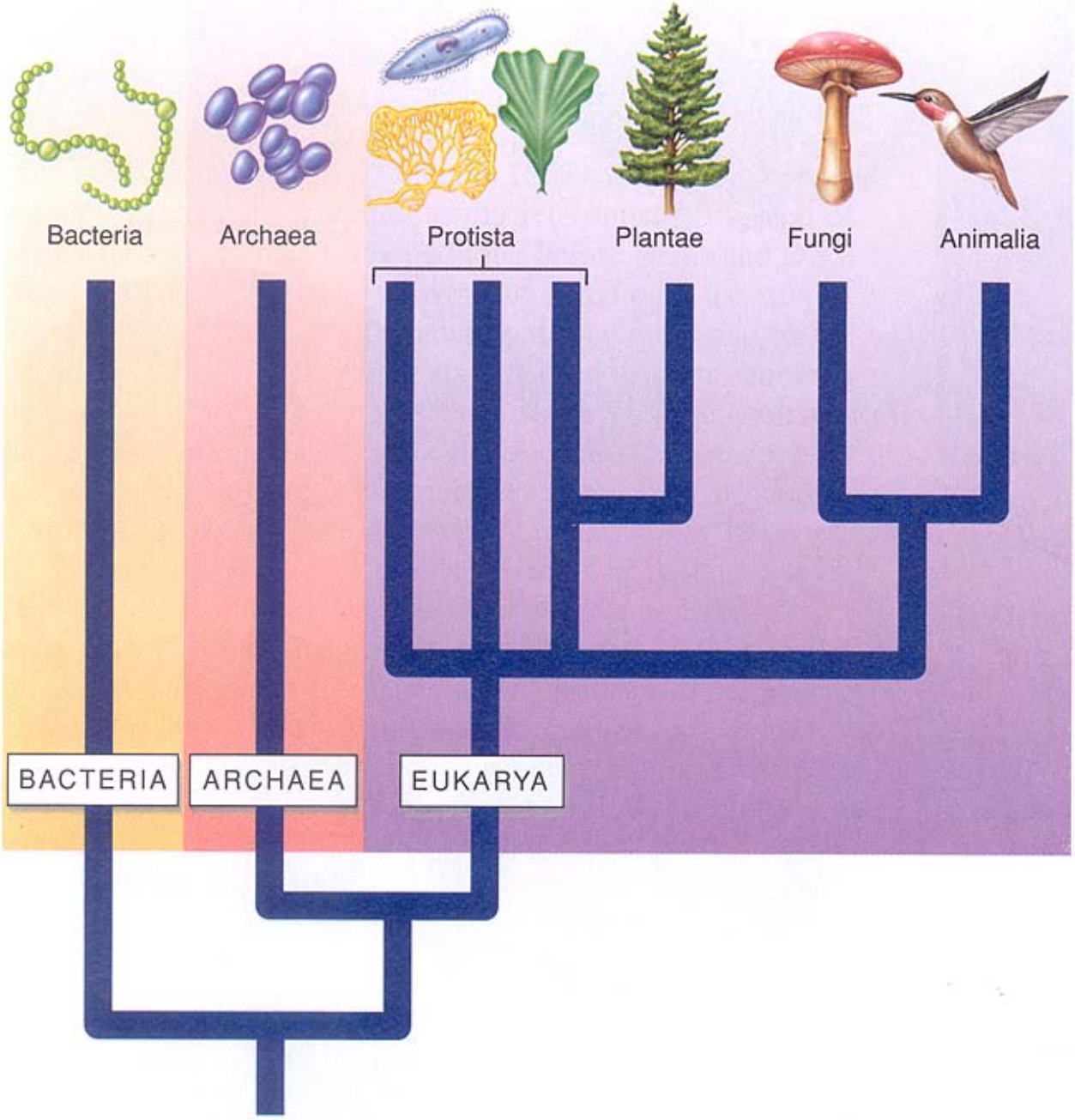
The number above each organism is the percent of the nucleotides in selected regions of that organism's genome that match those of the same regions in the human genome.

The Five Kingdoms

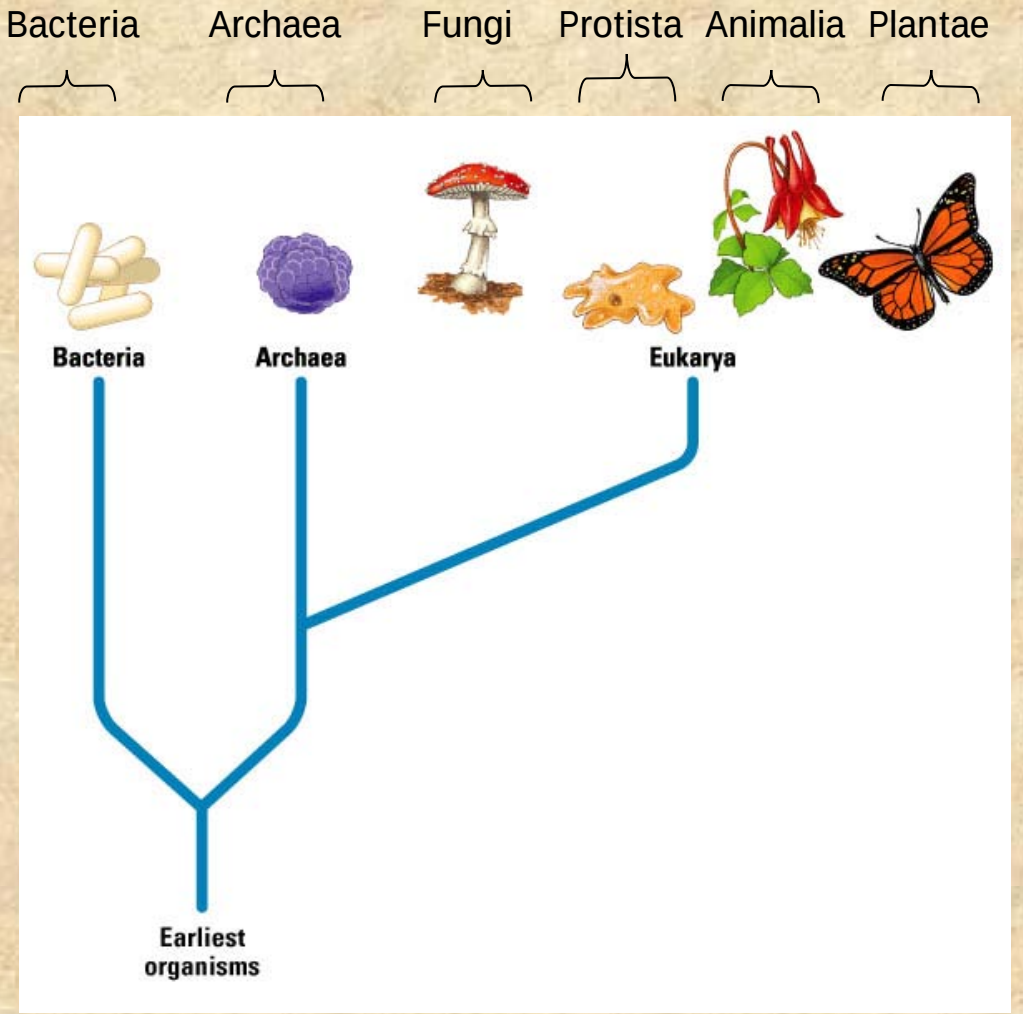




What is a *Biological Species*?


Bacteria
Archaea
Protista
Plantae
Fungi
Animalia
BACTERIA
ARCHAEA
EUKARYA

The Three Domains of Life



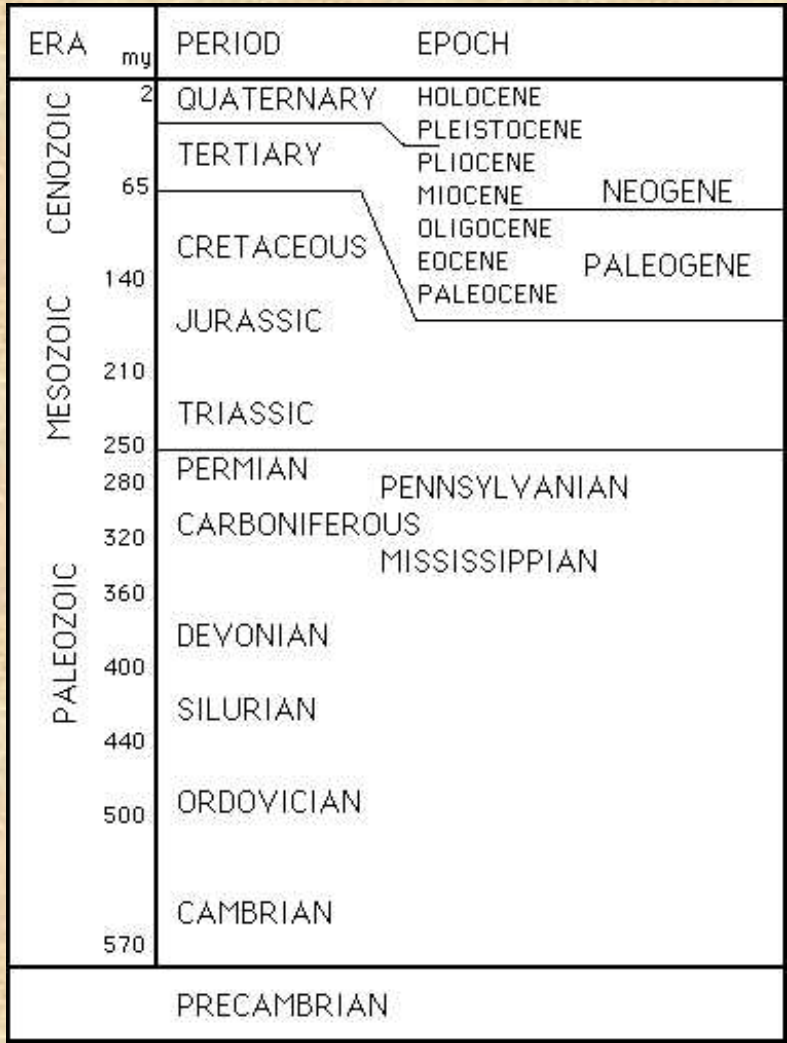
Mass Extinctions: Permian Triassic

- Permian Triassic (225 –250mya)

  Boundary between Paleozoic and Mesozoic

  Followed by adaptive radiation of reptiles

- Adaptive Radiation: Rapid evolution of species from a common ancestral stock



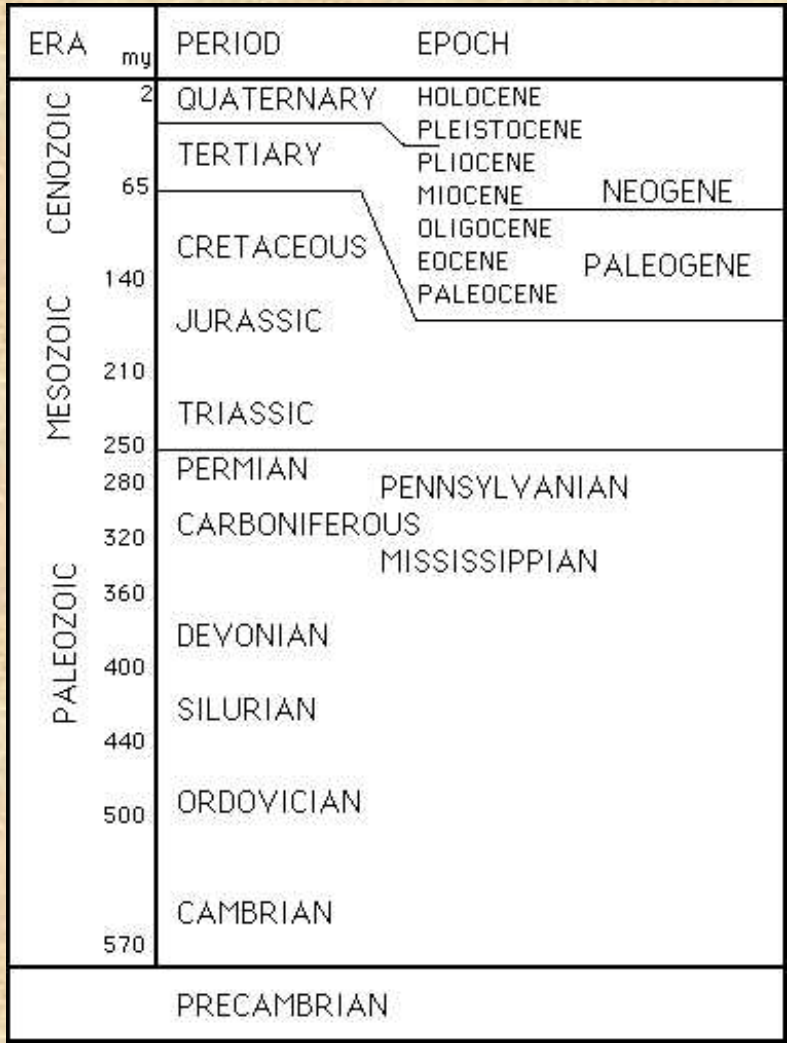
Mass Extinctions: Cretaceous-Tertiary

- Cretaceous - Tertiary Extinction

  65 Million years ago

  Extinction of the dinosaurs

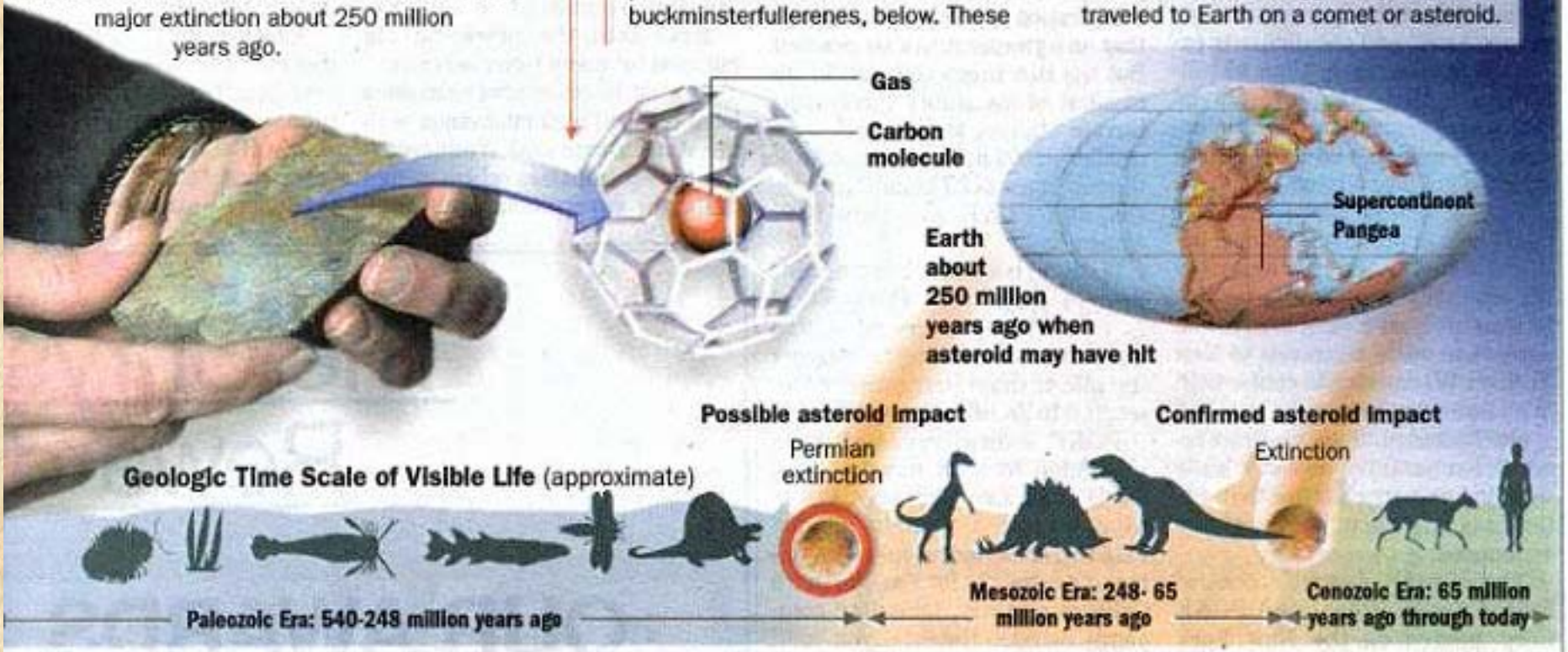
- Followed by adaptive radaition of mammals



Sudden Impact

Scientists have debated whether asteroids are the cause of catastrophic die-offs. The new focus of the discussion is on whether an asteroid caused major extinction about 250 million years ago.

A 250-million-year-old rock, left, that existed at the time of the massive extinction at the end of the Permian period contains carbon molecules called buckminsterfullerenes, below. These soccer ball-shaped molecules trapped gas within them when they formed. In this case, they contain gas that comes from outer space, suggesting they traveled to Earth on a comet or asteroid.



Cambrian period Age of trilobites 540-500 million years ago

Ordovician period Plants appear on land 500-438 million years ago

Silurian period First plants with water-conducting tissue 438-408 million years ago

Devonian period Age of fishes 408-360 million years ago

Carboniferous period First winged insects 360-280 million years ago

Permian period Age of amphibians 280-248 million years ago

Triassic period First dinosaurs and mammals 248-208 million years ago

Jurassic period Many dinosaurs, first birds and flowering plants 208-146 million years ago

Cretaceous period Dominance of dinosaurs 146-65 million years ago

Tertiary period Age of mammals 65-1.8 million years ago

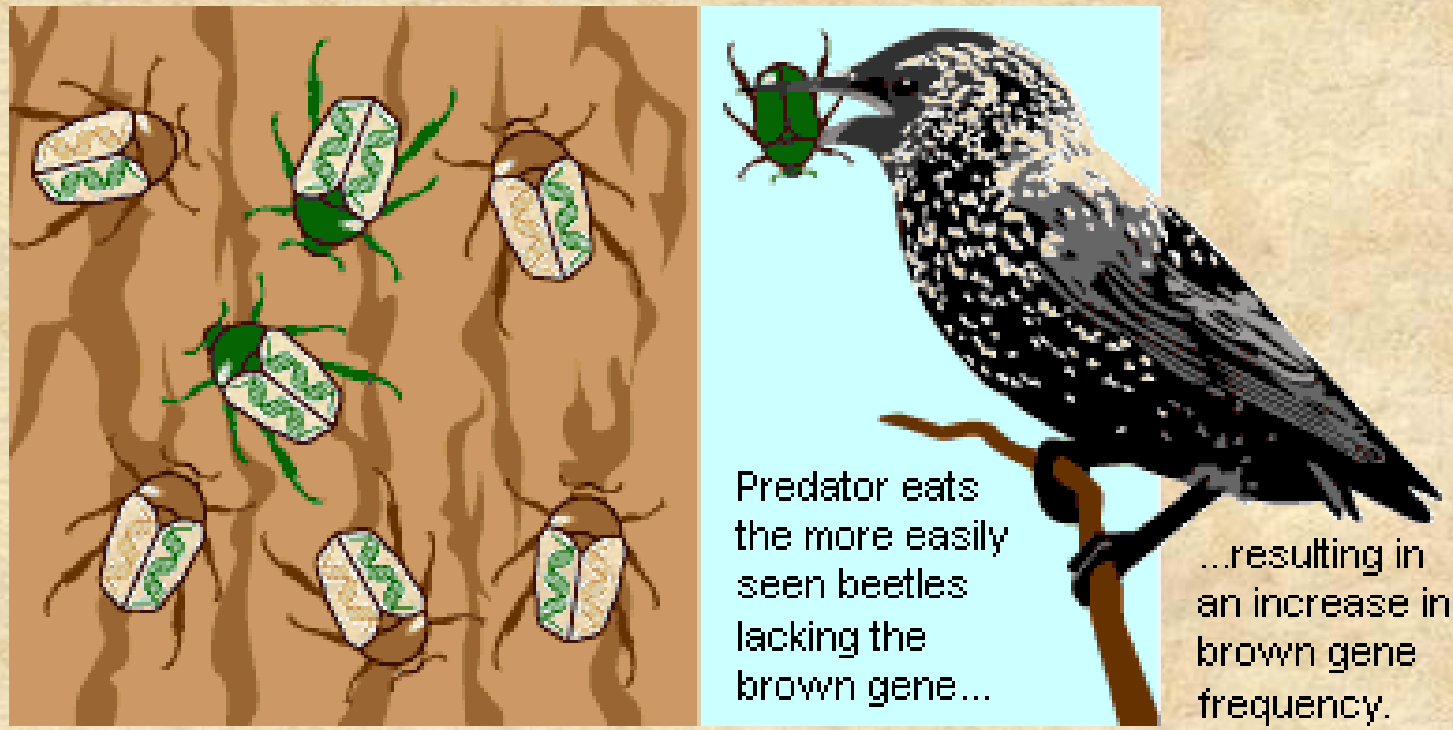
Quaternary period Age of man 1.8 million years ago through today

Mutation

- The ultimate source of genetic variation

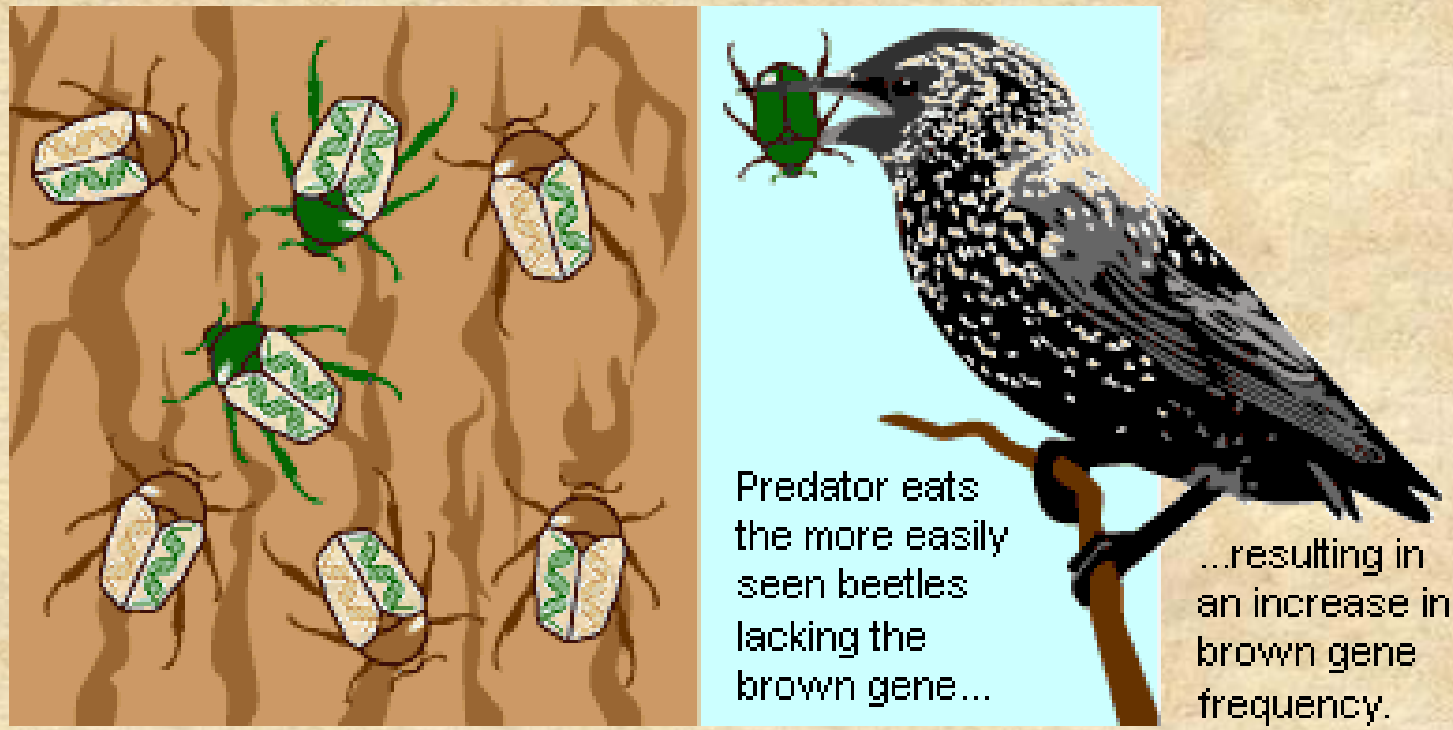
Some green genes randomly mutated to brown genes. Note that since any particular mutation is rare, this process alone cannot account for a big change in allele frequency over one generation.

Natural Selection



Beetles with brown genes escaped predation and survived to reproduce more frequently than beetles with green genes, so that more brown genes got into the next generation.

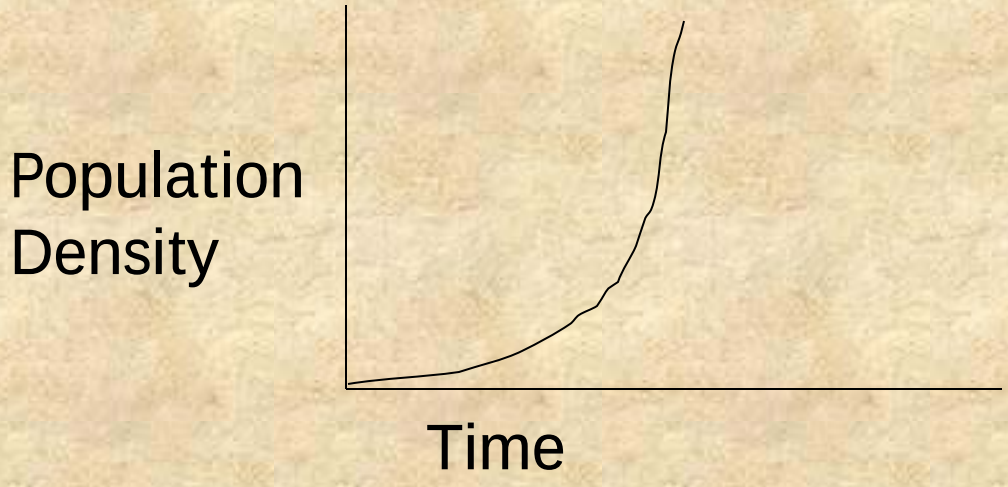
Natural Selection – results in a change in gene frequencies



Beetles with brown genes escaped predation and survived to reproduce more frequently than beetles with green genes, so that more brown genes got into the next generation.

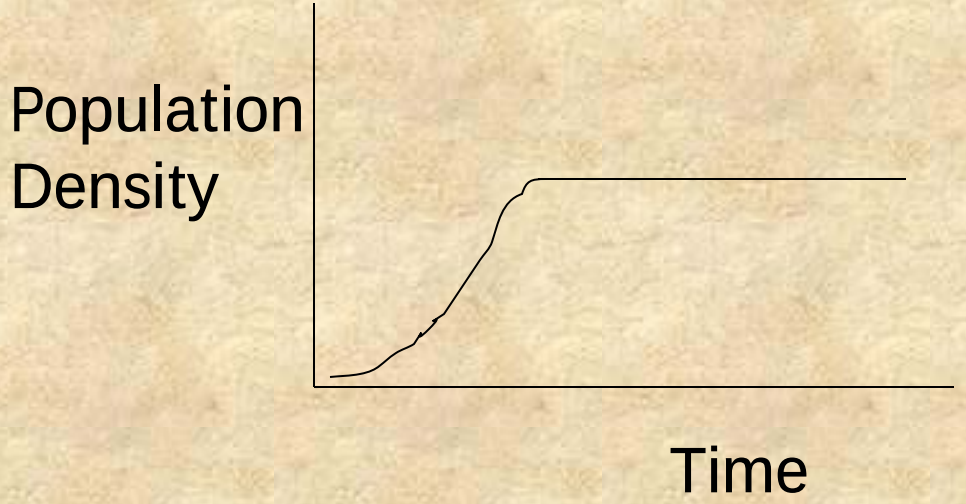
Natural Selection –

- More individuals are born in each generation than will survive and reproduce



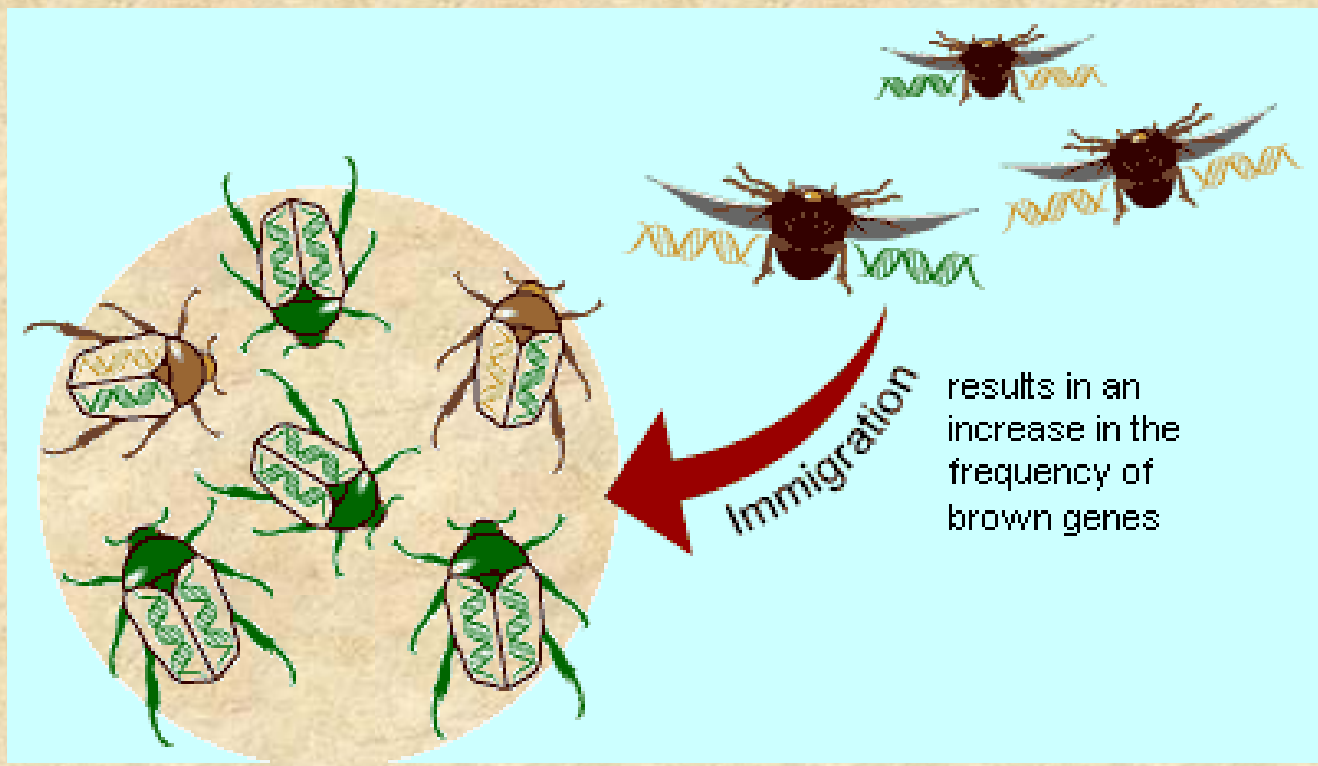
Natural Selection

- The more adapted individuals survive and reproduce



- Across generations a larger proportion of the population becomes adapted to the environment

Gene Flow (Migration)



Some beetles with brown genes immigrated from another population, or some beetles carrying green genes emigrated.