Big Idea 1: The process of evolution drives the diversity and unity of life.

Enduring understanding 1.C: Life continues to evolve within a changing environment.

Essential knowledge 1.C.1: Speciation and extinction have occurred throughout the Earth's history.

a. Speciation rates can vary, especially when adaptive radiation occurs when new habitats become available.

ORIGIN OF SPECIES

Main Idea

Speciation varies greatly in both its rate and the number of changes that are required to separate a new species from its parent population.

"The Rate of Speciation"

- The time it takes for geographical isolation to lead to reproductive isolation depends on a number a variables.
  - which genes mutate, the rate of mutations, extent of genetic drift, degree of environmental differences between the populations, generation times
- Intrinsic reproductive isolation leading to speciation may take thousands or millions of years or it may happen virtually "over night".

Patterns in the Fossil Record

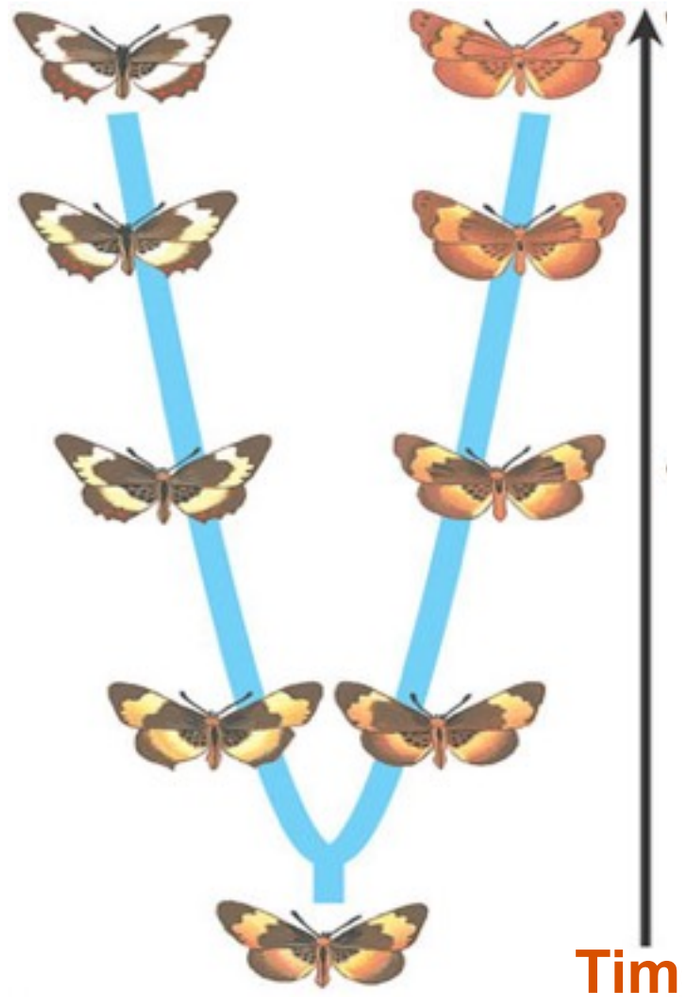
- The fossil record looks both static and dynamic.
- Some species appear in the fossil record virtually unchanged for over several strata (long time).
  - marine invertebrates
- While other species suddenly appear in the stratum, (short time)
  - ***punctuated equilibrium-Stephen Jay Gould***
- And yet others appear to gradually change over time.
  - ***gradualism-Charles Darwin***

Speciation Rates

- The fossil record and other experimental data suggest that speciation may occur relatively slowly (40 million years) or very quickly (4,000 years).
- The interval of time between speciation events includes the elapsed time from before populations of the newly formed species start to diverge + the time it takes for speciation to occur once divergence begins.
- **On average speciation events occur at a rate of 6.5 million years and rarely less then 500,000 years.**

- Darwin described speciation as a gradual change over time.

Gradualism model. Species descended from a common ancestor gradually diverge more and more in their morphology as they acquire unique adaptations.

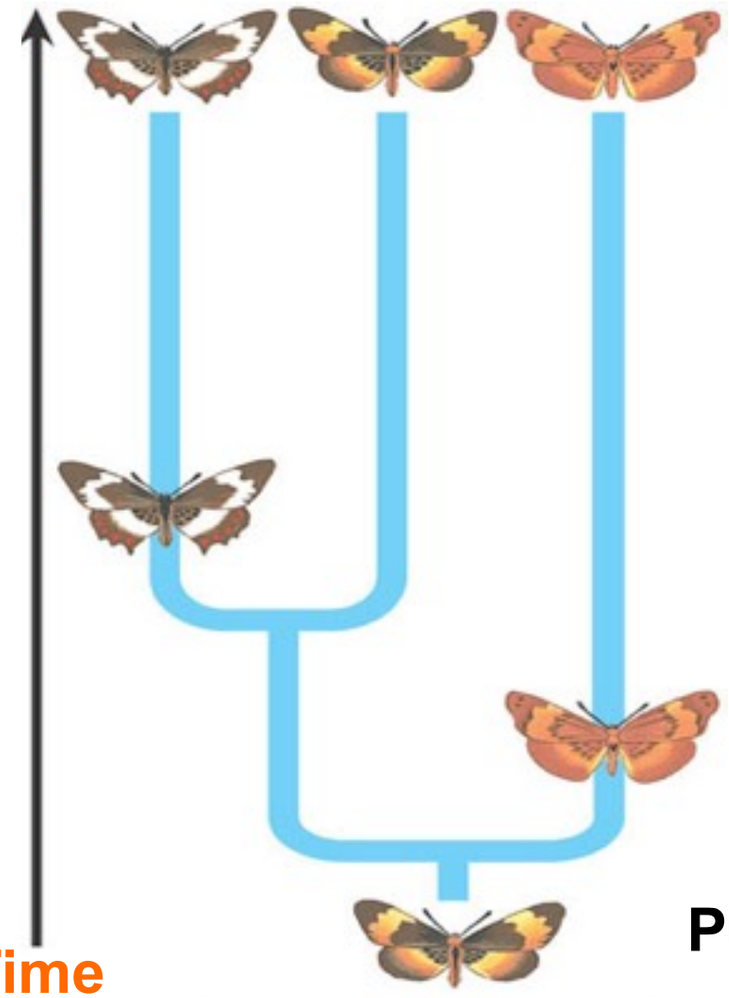


However a lot of fossil evidence looks very different from this.

- Contemporary biologists Stephen Jay Gould and Niles Eldridge proposed a different view of speciation.

Keep this in mind, say a species survives 5 million years, but the events that lead to speciation occur over 50,000 years, this is only 1% of its time on earth.

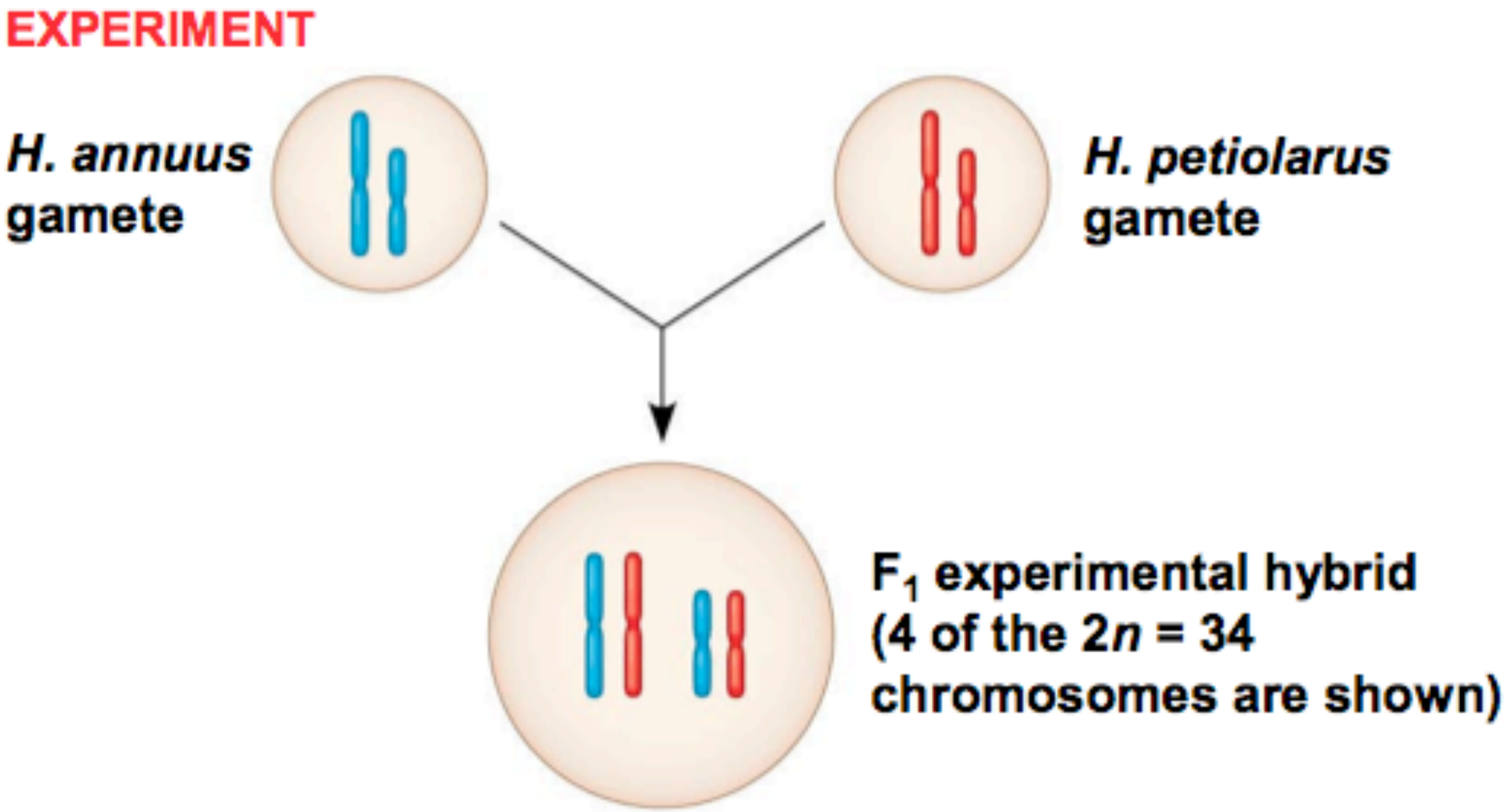
Since fossil formation is rare none of these fossil may exist only ones from the old and new species that lived for millions of years.



Many fossils appear similar for a long time, then exhibit abrupt changes in a short period of time followed by another period of stasis.

Punctuated equilibrium model.

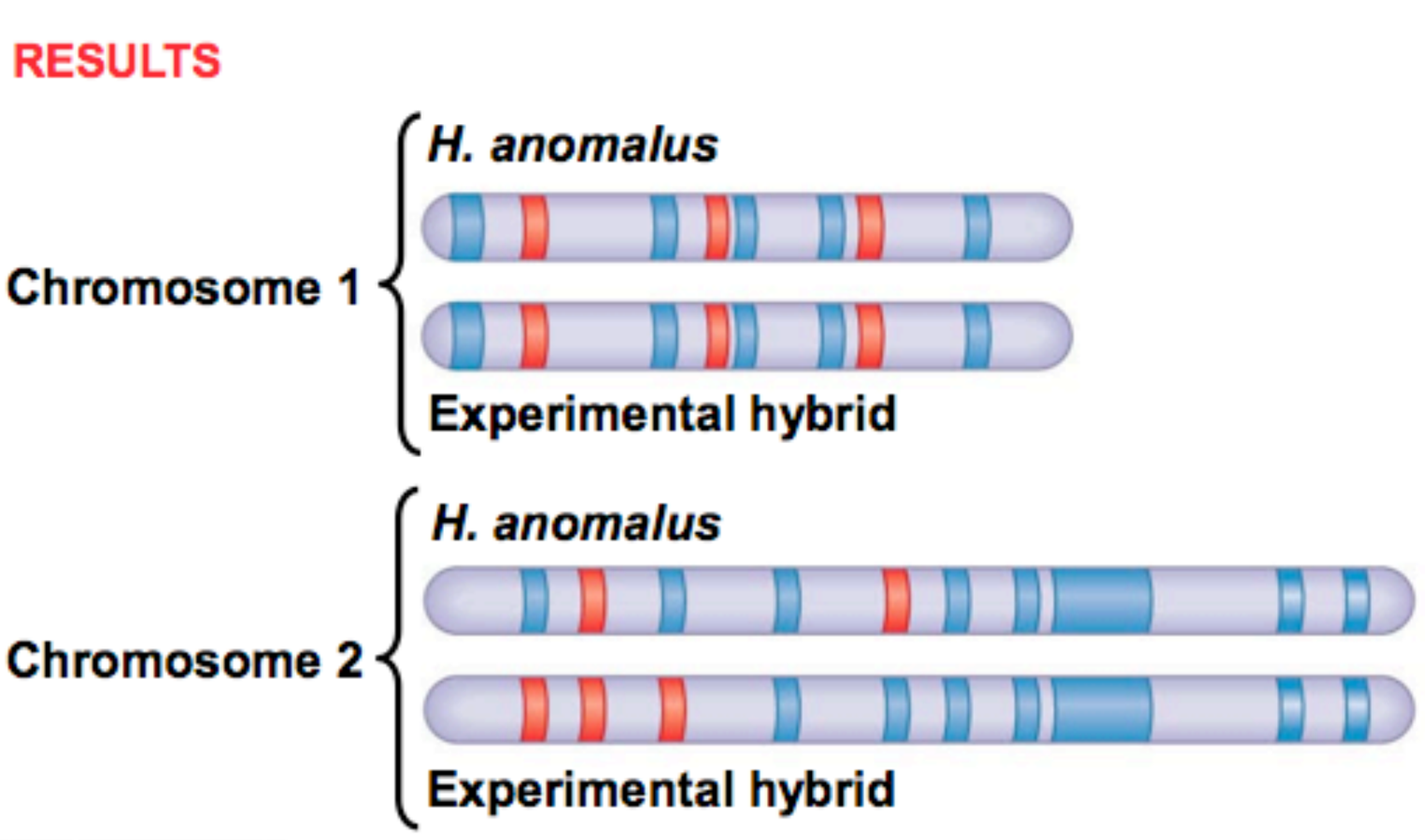
A new species changes most as it buds from a parent species and then changes little for the rest of its existence.



Indiana University, Loren Reiseberg and Colleagues crossed two parent sunflower species, *H. annus and H. petiolaris* to produce experimental hybrids in the lab (only 2 of the 17 chromosomes are shown)

Note that in the first generation (F1), each chromosome of the experimental hybrids consisted entirely of DNA from one or the other parent species. They then tested whether the F1 and subsequent generations of experimental hybrids were fertile. They also used species-species genetic markers to compare the chromosomes in the experimental hybrids with the chromosomes in the naturally occurring hybrid *H. anomalus*

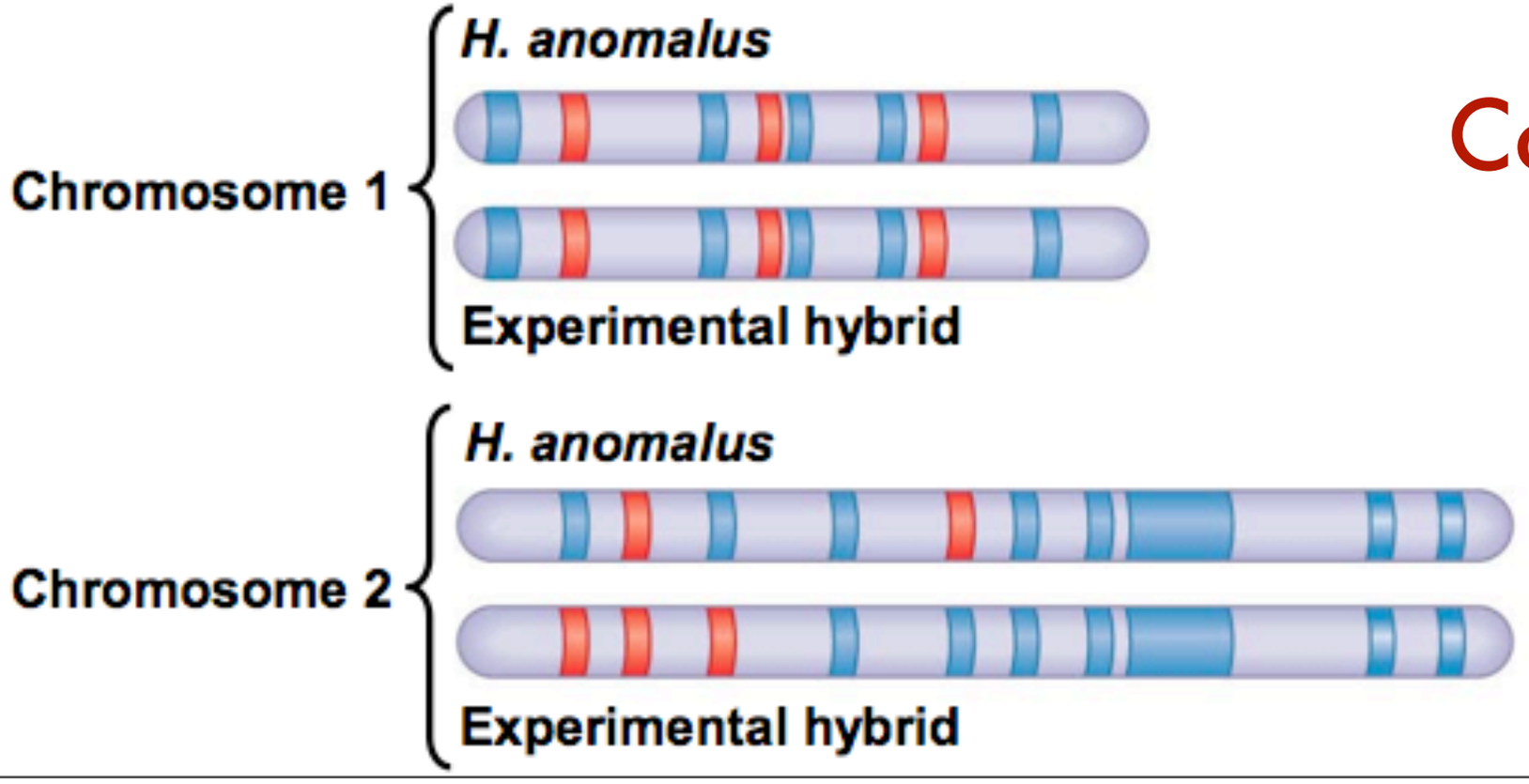
Although only 5% of the F1 experimental hybrids were fertile, after just 4 more generations the hybrid fertility rose to more than 90%. The chromosomes of individuals from this fifth hybrid generation differed from those in the F1 generation but were similar to those in the *H. anomalus* individuals from the natural populations:



Over time, the chromosomes in the population of experimental hybrids became similar to the chromosomes of *H. anomalus* individuals from the natural populations.

This suggests that the observed rise in fertility of the experimental hybrids occurred as natural selection eliminated regions of DNA from the parent species that were not compatible with one another. Overall, it appeared that the initial steps of the speciaition process occurred rapidly and could be mimicked in a laboratory experiment.

Conclusion



The Genetics of Speciation

- A fundamental question of evolutionary biology persists: How many genes change when a new species forms?
- Depending on the species in question,speciation might require the change of only a single allele or many alleles
- For example, in Japanese *Euhadra* snails, the direction of shell spiral affects mating and is controlled by a single gene
- In other species,speciation can be influenced by larger numbers of genes and gene interactions

- In monkey flowers (*Mimulus*), two loci affect flower color, which influences pollinator preference
- Pollination that is dominated by either hummingbirds or bees can lead to reproductive isolation of the flowers

(a) Typical *Mimulus lewisii*

(b) *M. lewisii* with an *M. cardinalis* flower-color allele

(c) Typical *Mimulus cardinalis*

(d) *M. cardinalis* with an *M. lewisii* flower-color allele

From Speciation to Macroevolution

- Speciation can begin with a few minor changes to an organism.
- Over time these changes may accumulate and become more pronounced.
- Eventually these changes may lead to new groups of organisms that vary greatly from their ancestors.
- Some groups grow in size while others go extinct.
- The cumulative effect of speciation and extinction have shaped the evolution changes documented by the fossil record.

RECALL:Evolution is Not Goal Oriented

- Whether speciation occurs slowly and gradually or whether it occurs bursts, evolution has no end point in mind.
- Evolution "tinkers" with each organism making slight modifications some of which will be beneficial and others that are not.

Overtime this "tinkering" has lead to three key features in the natural world!

1. Organisms are well suited to their environments.

2. Organisms share many characteristics.

3. Organisms are remarkably diverse.

Essential knowledge 1.C.1: Speciation and extinction have occurred throughout the Earth's history.

b. Species extinction rates are rapid at times of ecological stress. [See also **4.C.3**]

To foster student understanding of this concept:

- Five major extinctions
- Human impact on ecosystems and species extinction rates

- ✘✘ *The names and dates of these extinctions are beyond the scope of this course and the AP Exam.*

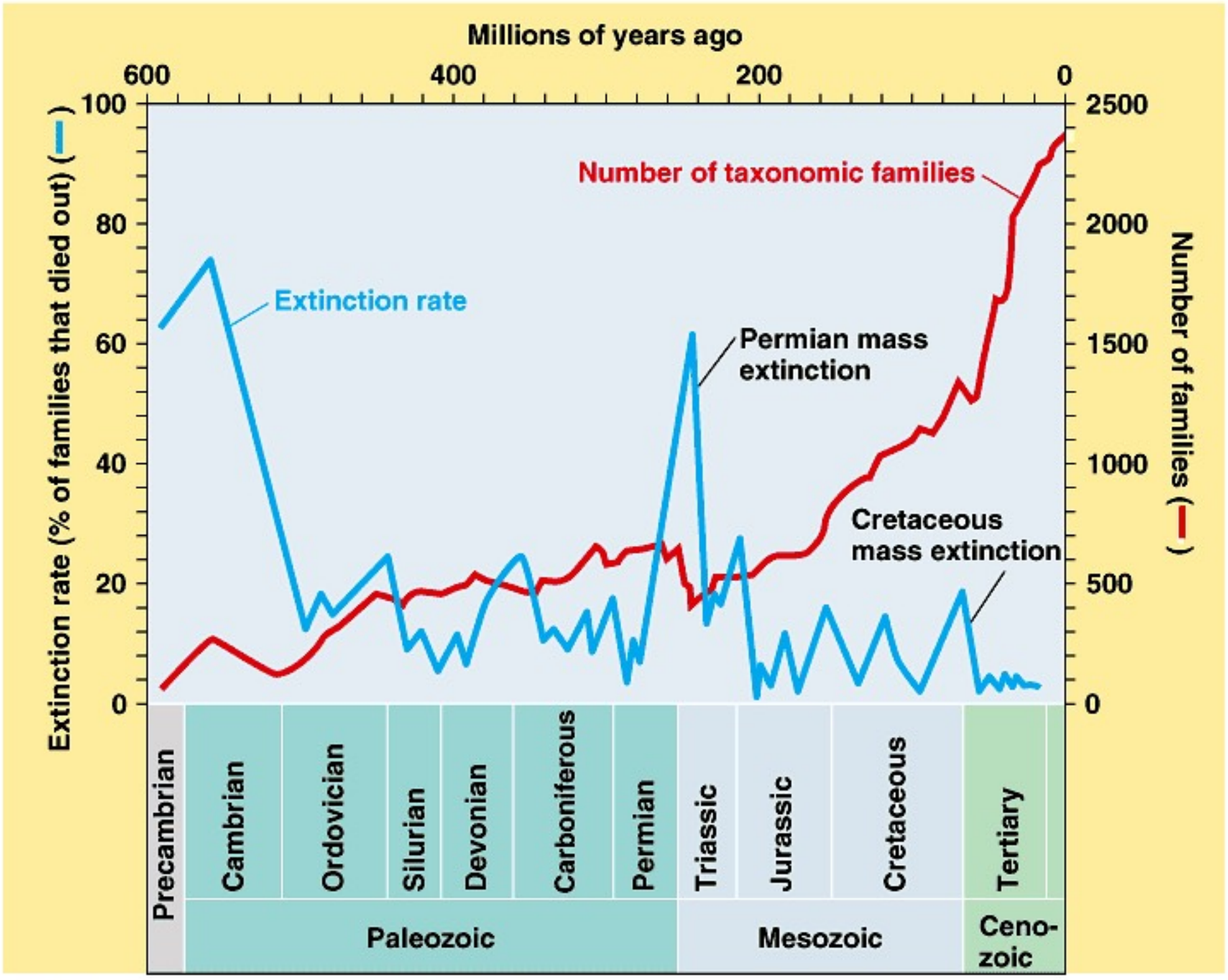
A Rise, A Fall and Something New

- The the theme of this presentation...Change!
  - The earth has witnessed episodic explosions of life, remarkable speciation events and widespread adaptive radiations.
    - *cambrian explosion, colonization of land, time of dinosaurs, the rise of mammals*
- The earth has also witnessed episodic mass extinctions.
  - *5 in total, including the Permian extinctions and the Cretaceous extinctions*

Life is on a very long roller coaster ride!

A Rise, A Fall and Something New

Life is on a very long roller coaster ride! **BUT WHY?**



A Rise, A Fall and Something New

- **Change!**
  - The earth is forever changing, episodic large scale geological events have played a big part
    - *production of oxygen, meteor impacts, ice ages, climate change, volcanic eruptions, methane release,*

A Rise, A Fall and Something New

Mass Extinctions Past—and Present?

TIMELINE OF EXTINCTION marks the five most widespread die-offs in the fossil history of life on Earth.

END ORDOVICIAN
DURATION: 10 million years (my)
MARINE GENERA OBSERVED EXTINGUISHED: 60%
CALCULATED MARINE SPECIES EXTINCT: 85%
SUSPECTED CAUSE: Dramatic fluctuations in sea level

Trilobite

Placoderm

LATE DEVONIAN
DURATION: <3 my
MARINE GENERA OBSERVED EXTINGUISHED: 57%
CALCULATED MARINE SPECIES EXTINCT: 83%
SUSPECTED CAUSES: Impact, global cooling, loss of oxygen in oceans

END PERMIAN
DURATION: Unknown
MARINE GENERA OBSERVED EXTINGUISHED: 82%
CALCULATED MARINE SPECIES EXTINCT: 95%
SUSPECTED CAUSES: Dramatic fluctuations in climate or sea level; asteroid or comet impacts; severe volcanic activity

Rugose coral

Phytosaur teeth

END TRIASSIC
DURATION: 3 to 4 my
MARINE GENERA OBSERVED EXTINGUISHED: 53%
CALCULATED MARINE SPECIES EXTINCT: 80%
SUSPECTED CAUSES: Severe volcanism; global warming

END CRETACEOUS
DURATION: <1 my
MARINE GENERA OBSERVED EXTINGUISHED: 47%
CALCULATED MARINE SPECIES EXTINCT: 76%
SUSPECTED CAUSES: Impact; severe volcanism

Mosasaur

Millions of years ago

570 510 439 409 363 290 248 210 146 65 1.64

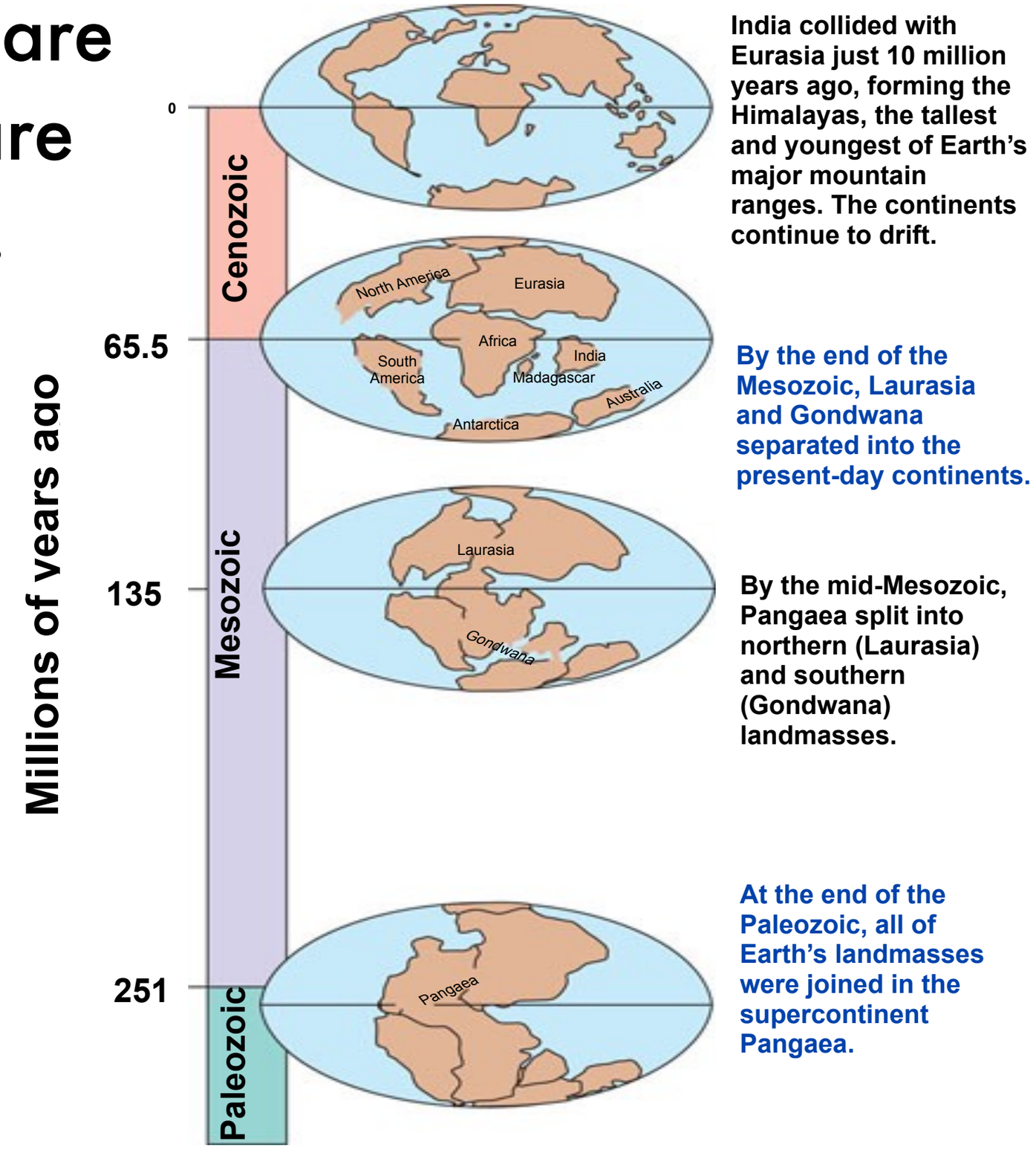
Cambrian Ordovician Silurian Devonian Carboniferous Permian Triassic Jurassic Cretaceous Tertiary Quaternary

A Rise, A Fall and Something New

- **Change!**
  - Even on a slower acting or smaller scale the earth is dynamic.
    - *plate tectonics move land masses, mountains are formed, lakes created, seas disappear, rain patterns shift,etc,*

A Rise, A Fall and Something New

The earth's continents are not stationary, they are continually moving.



India collided with Eurasia just 10 million years ago, forming the Himalayas, the tallest and youngest of Earth's major mountain ranges. The continents continue to drift.

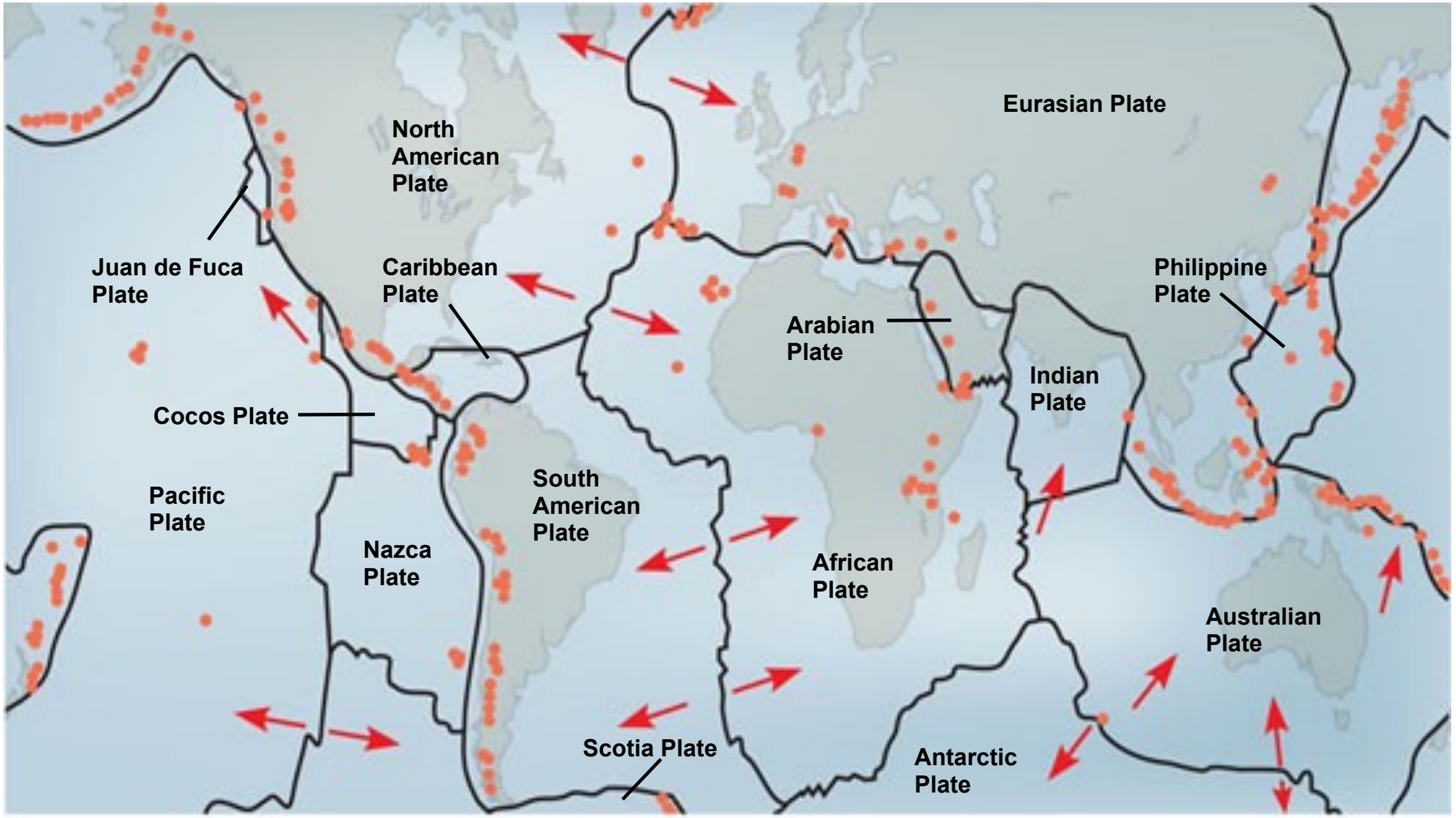
By the end of the Mesozoic, Laurasia and Gondwana separated into the present-day continents.

By the mid-Mesozoic, Pangaea split into northern (Laurasia) and southern (Gondwana) landmasses.

At the end of the Paleozoic, all of Earth's landmasses were joined in the supercontinent Pangaea.

A Rise, A Fall and Something New

The earth's plates either pull apart or crash into one another. The boundaries of these plates are highly active (earth quakes/volcanoes).



A Rise, A Fall and Something New

- **The "Two": the Earth and its Organisms are extricably tied together!**
  - The change of one effects the other
    - Are we now on the verge of a 6th major extinction?
    - Will human impact on on planet be added to the list of causes for mass extinction?
      - *4 of the 5 mass extinctions did occur when earth's temperature were abnormally high*

Conservation Ecology

Main Idea: Humans benefit directly and indirectly from biodiversity.

Main Idea: Unfortunately human activities are decreasing biodiversity.

Threats to Biodiversity

- Humans are the main causal agent of biodiversity loss.
- There are 4 major threats to biodiversity.
  - Habitat Loss, Invasive Species, Overharvesting & Global Change.

1. Habitat Loss

- Human alteration of habitats is the single greatest threat to habitat loss.
  - Agriculture, Urban Development, Forestry, Mining and Pollution.
- Habitat loss often results in extinction.

1. Habitat Loss

- **98% of tropical dry forests in Mexico and Central America have been cleared.**
- **90% of tropical rain forests in Veracruz, Mexico have been cleared.**
- **93% of Coral Reefs worldwide are damaged.**
  - **At the current rate 40-50% of all coral reefs could disappear by 2050.**

2. Invasive Species

- Non-native species moved intentionally or accidentally in new geographic areas.
  - Free from predators, pathogens and parasites their populations grow rapidly and disrupt community interactions.

2. Invasive Species

- Non-native species disrupt community interactions by preying on native species or by out competing them.
  - Invasive species have contributed to 40% of all extinctions since 1750.
  - They are costly and worldwide problem.
    - Examples include: Kudzu, Brown Tree Snake, Zebra Mussel

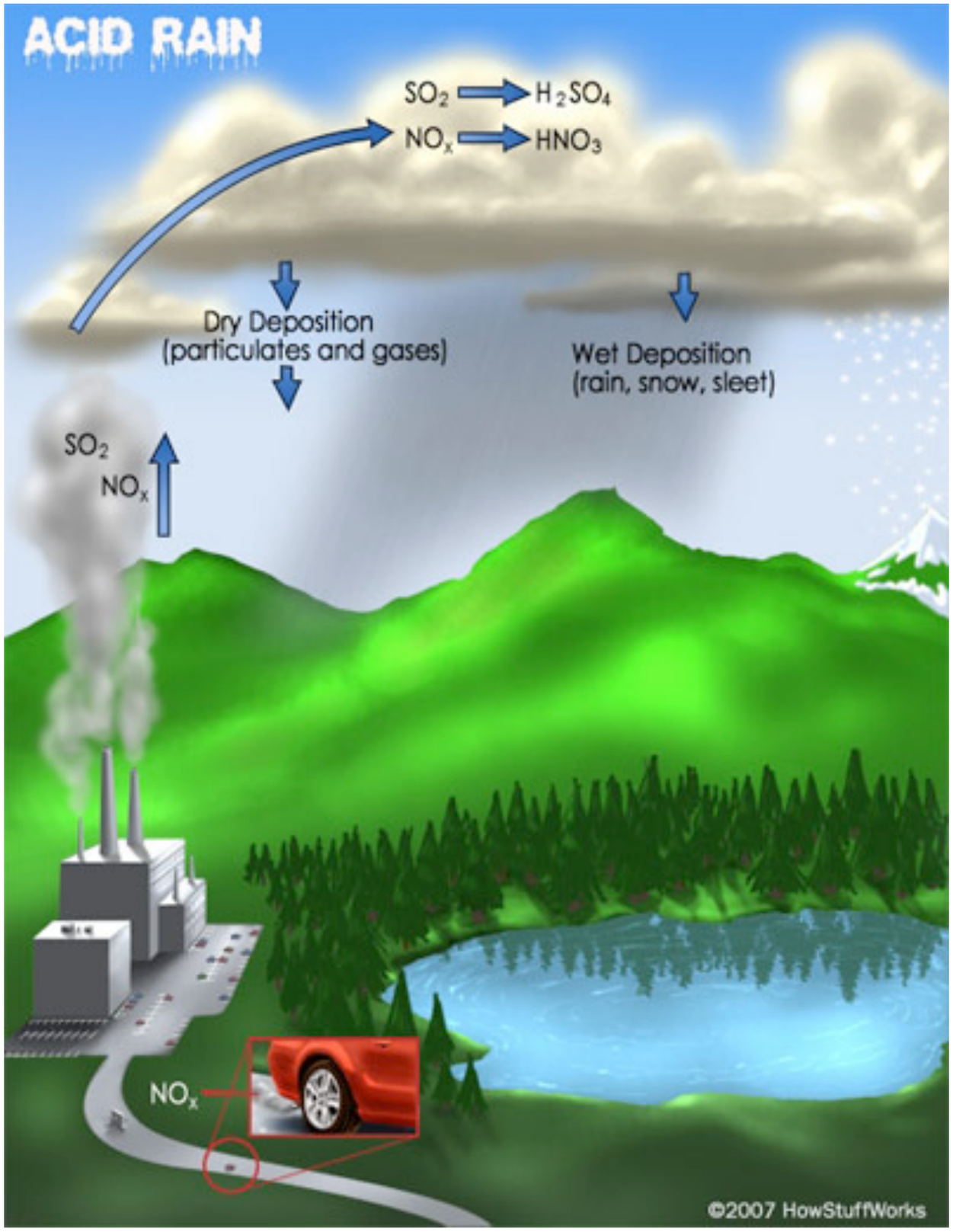
3. Overharvesting

- Harvesting organisms at a rate that exceeds the populations ability to rebound.
  - Species with small habitats and/or low reproductive rates are especially vulnerable.
    - Ex. Great Auk now extinct, Elephants once decimated

When the giant flightless birds called moa were overexploited to the point of extinction,[4] the giant Haast's eagle that preyed on them also became extinct[5]

4. Global Change

- Global Change includes changing *climates* and *atmospheric chemistry*.
- *Acid Precipitation* is one of the first examples of global change.
  - rain, sleet, fog, snow, etc with a pH less than 5.2
- Burning wood releases sulfur and nitrogen that react with water to from acids
- Acid precipitation harms both aquatic and terrestrial ecosystems
  - Regulations have reduced sulfur emissions by 40% between 1993 and 2008 however nitrogen emissions are still increasing


ACID RAIN
SO_2 → H_2SO_4
NO_x → HNO_3
Dry Deposition
(particulates and gases)
Wet Deposition
(rain, snow, sleet)
SO_2
NO_x
NO_x
©2007 HowStuffWorks

Conservation Ecology

Main Idea: The earth's habitats and climate are changing.

Main Idea: The rate of change is greater than changes of the past.

Main Idea: Human actions are responsible for some of these changes and the rate at which they are occurring.

EARTH IS CHANGING RAPIDLY AS A RESULT OF HUMAN ACTIONS

Nutrient Enrichment

- Human activity removes nutrients from one part of the biosphere and adds them to another! Consider the following..
  - Small scale: Floridian consumes corn grown in Iowa.
  - Large scale: Fertilizer runs off from that same farm in Iowa into the Mississippi River.
  - Additionally humans are adding synthetic, novel and some toxic nutrients to ecosystems as well

Lets take a closer look at "farming"...

Toxins in the Environment

- Humans release a variety of toxins, often times synthetic (novel to organisms) into the environment.
- Many toxins can't be degraded by microorganisms and persist in the environment for years.
  - In fact some chemicals released are benign only to be later converted into toxic forms
    - Ex. Insoluble mercury dumped in waterways is converted by bacteria on the bottom into methyl mercury; water soluble and highly toxic compound.
- Some toxins are excreted by organisms but many accumulate in the fatty tissue.
  - These toxins become more concentrated with each successive trophic level. ***(biological magnification)***
  - Two well documented examples illustrate this process.
    - The industrial compound PCB's & the pesticide DDT

Greenhouse Gases & Global Warming

1. Rising atmospheric CO_2 levels

- Since the industrial revolution the levels of CO_2 in atmosphere have been increasing. (estimates of 274 ppm in 1850)
- Since 1958 we have been able to accurately measure CO_2 levels in the atmosphere. (1958 = 316ppm), (today it exceeds 385 ppm)
- Computer models estimate that in 60 years the amount of CO_2 in the atmosphere will be double what it was in the 19th century.
    - These rising levels are not questioned by even the skeptics.

Depletion of Atmospheric Ozone

- Like atmospheric levels of CO_2 the levels atmospheric ozone (O_3) have been changing as well
  - Life on earth is protected from the damaging effects of UV radiation by layer of ozone located in the stratosphere.
- Ozone has changed as a result of human activities.
  - The destruction of ozone results primarily from the accumulation of chloroflourocarbons (CFC's), chemicals used in refrigeration and manufacturing.

Learning Objectives

LO 1.20 The student is able to analyze data related to questions of speciation and extinction throughout the Earth's history. [See **SP 5.1**]

LO 1.21 The student is able to design a plan for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout the Earth's history. [See **SP 4.2**]