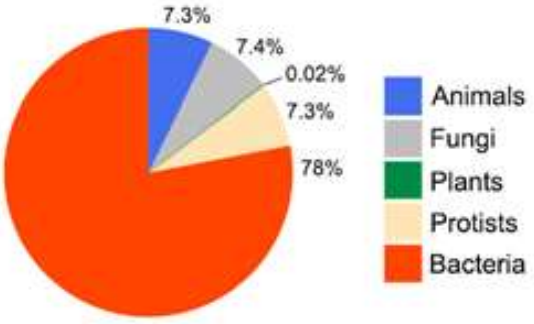
APES CHAPTER 5 NOTES (MRS. BAUCK):
EVOLUTION OF BIODIVERSITY

MODULE 14: The Biodiversity of Earth

I. Estimating Number of Species
   A. scientists have classified ~2 million species
   B. difficulties with estimation
      1) some species are difficult to find
      2) some species are nocturnal
      3) some live in inaccessible locations

EARTH"S BIODIVERSITY



Source: Phys.org (2016)

II. Measuring Biodiversity
   A. **species richness**—*the number of species in a given area*
   B. **species evenness**—*the proportion of individuals within different species living in an area*
   C. https://phys.org/news/2018-03-state-earth-species.html
   D. Shannon biodiversity index (H)

$$H = -\sum_{i=1}^{n} p_i \ln(p_i)$$

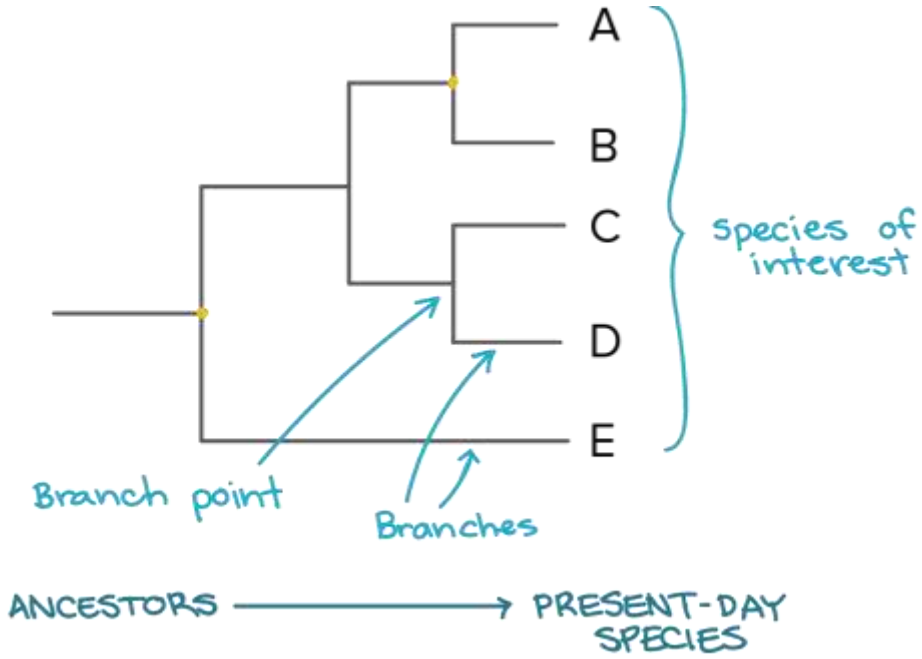
n = species richness

p_i = proportion of n made up of the *i*th species

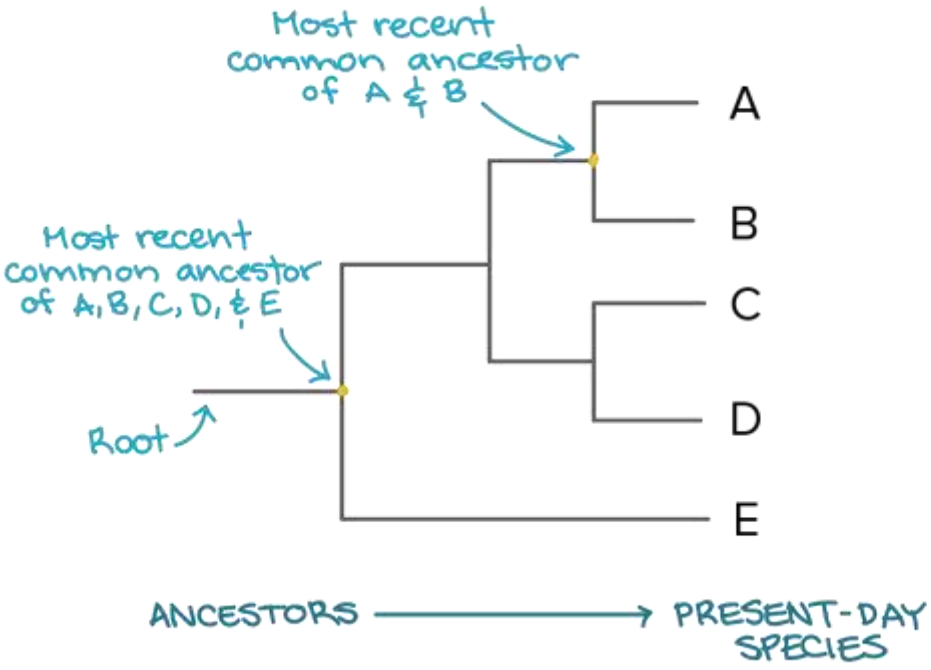
III. Phylogeny
   A. from www.tolweb.org :

"Evidence from morphological, biochemical, and gene sequence data suggests that all organisms on Earth are genetically related, and the genealogical relationships of living things can be represented by a vast evolutionary tree, the **Tree of Life**. The Tree of Life then represents the **phylogeny** of organisms, i. e., the history of organismal lineages as they change through time. It implies that different species arise from previous forms via descent, and that all organisms, from the smallest microbe to the largest plants and vertebrates, are connected by the passage of genes along the branches of the phylogenetic tree that links all of Life."

B. phylogenetic tree



Source: Khan Academy



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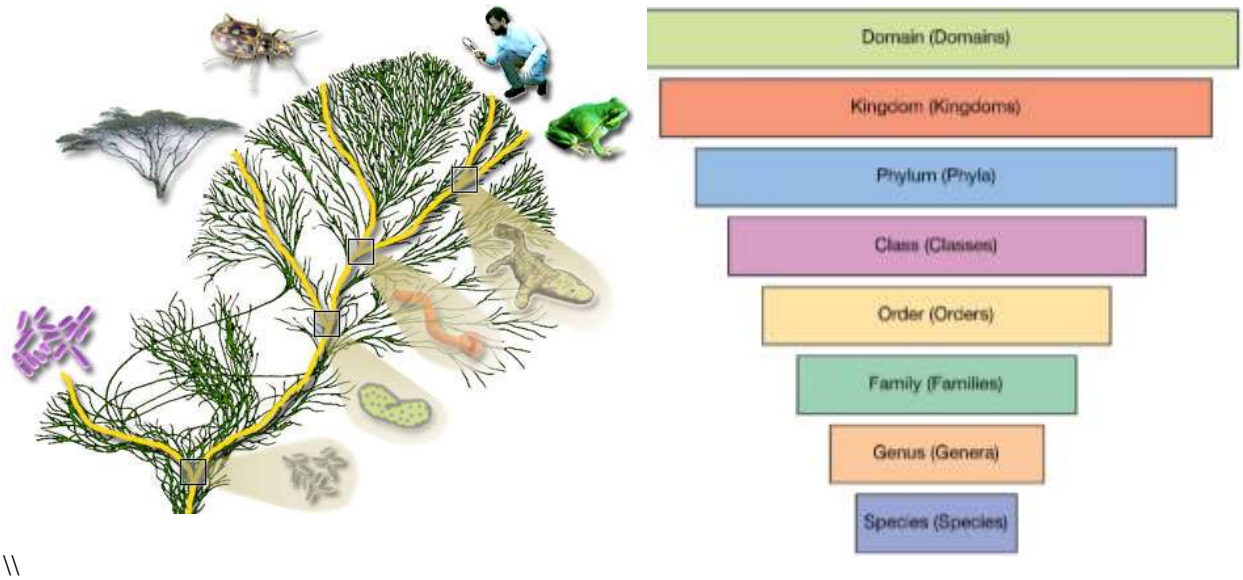

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MODULE 15: How Evolution Creates Biodiversity

I. Genetics review

A. background info

1) *traits*—characteristics of an organism
2) *DNA*—deoxyribonucleic acid
   a) double helix molecule comprising *chromosomes*
   b) contains genetic material
   c) *nucleotides*: composed of sugar, phosphate, nitrogen base

DNA sugar = deoxyribose bases = adenine (A) , guanine (G), cytosine (C), thymine(T)
RNA sugar = ribose bases = adenine (A) , guanine (G), cytosine (C), uracil (U)

   d) genetic code (arrangement) is translated into proteins
   e) **gene**—*segment of DNA coding for a specific protein*
3) *mitosis*—cell division
4) *meiosis*—formation of gametes
5) **genotype—***set of genes in an individual*
6) **phenotype—***the appearance of the individual, as dictated by the genotype*

B. *genetic variation*— genetic differences between individuals in a population

1) *allele*—alternate forms of the same gene
2) *gene pool*—all the genes in a population
3) inheritance patterns
   a) common Mendelian pattern = dominant and recessive
   b) incomplete dominance = traits mask one another
   c) codominance = traits are equally expressed
   d) multiple alleles = inheritance pattern (human blood types)
   e) polygenic inheritance = complex inheritance pattern involving multiple genes interacting to produce the traits
   f) sex-linked = traits in question are carried only by the X chromosome

C. **mutation**—*a random mistake in the gene sequence* (the sequence is read in sets of three)

1) point mutation (add one)
   THE DOG BIT THE CAT = THE DOG BIT THE BAT
2) deletion (one or more is missing)
   THE DOG BIT THE CAT = THE DO_B ITT HEC AT
3) insertion (add extra)
   TH_E DOG BIT THE CAT = THX EDO GBI TTH ECA T
4) inversion (taken out and reinserted backwards)
   THE DOG BIT THE CAT = THE DOG BIT THE TAC
5) frame shift mutation—when a mutation changes the meaning of the sequence, rendering it meaningless
6) **recombination**—part of one chromosome breaks off and reattaches in a different place (translocation)
7) *lethal mutation*—results in the death of the individual
8) *neutral mutation*—does not benefit or harm the individual

II. What is a *theory*? – a review

Some people say, "It's just a theory. You can't prove it." Let's review what a scientific theory is…

A. a *thoroughly tested* scientific model that explains why
B. cannot be proven but has *substantial scientific evidence* to back it up
C. the *best explanation* we have for a phenomenon
D. can be *repeatedly tested and verified* in accordance with the scientific method; substantiated through repeated experiments or testing
E. A theory in science is much different from the everyday "slang" definition of theory!

III. Natural Selection

A. **evolution**—*descent with modification; changes in genetic makeup of a population over time*
B. evolutionary processes
   1) natural selection
   2) artificial selection
   3) random processes: mutations, genetic drift, gene flow

C. from Khan Academy:

"Evolution is how species experience heritable (passed from one generation to the next) changes in their traits over time. In order for evolutionary changes to occur, many generations over thousands to millions of years are often required – meaning, these adaptations don't happen overnight!"

D. from Evolution 101

"In biology, *evolution* is the process by which populations of organisms acquire and pass on novel traits from generation to generation, affecting the overall makeup of the population and even leading to the emergence of new species. Darwin and Wallace proposed that evolution occurs because a heritable trait that increases an individual's chance of successfully reproducing will become more common, by inheritance, from one generation to the next, and likewise a heritable trait that decreases an individual's chance of reproducing will become rarer...

The *modern evolutionary synthesis* generally denotes the combination of Charles Darwin's theory of the evolution of species by natural selection, Gregor Mendel's theory of genetics as the basis for biological inheritance, and mathematical population genetics. Essentially, the modern synthesis (or neo-

Darwinism) introduced the connection between two important discoveries; the units of evolution (*genes*) with the mechanism of evolution (*selection*)…

Biological evolution, simply put, is *descent with modification.*"

E. *selective pressures*—biotic and abiotic limiting factors of *environmental resistance*
F. *differential reproduction*—some members of a species reproduce more than others
G. **natural selection**—*natural modification of the gene pool*

H. **evolution by natural selection—***environmental factors determine which individuals survive and reproduce*
   1) individuals produce an excess of offspring
   2) not all offspring can survive
   3) individuals have different traits
   4) trait differences can be passed down to offspring from parents
   5) trait differences indicate differences in the ability to survive and reproduce

I. **adaptation** to the environment to promote **fitness**— *survival and reproduction*
   1) deal with limiting factors of environmental resistance
   2) obtain food (nutrients) and water
   3) avoid/escape predators
   4) resist parasites and disease
   5) attract mates (or pollinate)
   6) migrate (or disperse seeds)

J. limits of change
   1) choices

THREE CHOICES WHEN FACED WITH SELECTIVE PRESSURE:

- adaptation (change)
- migration (leave)
- extinction (gone forever)

   2) species adapt to deal with environmental resistance
   3) species adapt to each other
   4) ecosystems can change in character and composition

K. evolution in perspective
   1) the fossil record
      a) age of Earth: ~4.55 billion years old (4,550,000,000)
      b) oldest rocks found on Earth: ~3.8 billion yrs. old (3,800,000,000)
      c) age of our solar system: ~4.559 billion yrs. old (4,559,000,000)
      d) age of our sun: ~4.49 billion yrs. old (4,490,000,000)
   2) *"Cambrian explosion"*—most major groups of animals first appear in the fossil record
   3) **macroevolution**—*evolutionary change at or above the species level*
   4) **microevolution—** *evolutionary change below the species level (allelic frequency)*
   5) stewardship of life—to *prevent extinction* and *preserve biodiversity*
   6) **mass extinction**—a cyclical event; five major ones in Earth's history (some say we may be in the middle of the sixth one now)

IV. **Artificial Selection** – change through selective breeding

A. **evolution by artificial selection**—*humans determine which individuals breed, according to preselected desired traits*

B. *selective breeding*—breeding is done to bring out specific traits; an example of **artificial selection**

C. examples: pure-bred animals, flowers, all GMOs

Source: UC Berkeley

V. Random processes of evolution

A. **mutation**—see p. 3 notes

B. **gene flow**—*the process by which individuals moving from one population to another, altering the genetic makeups of both populations*

C. **genetic drift**—*changing the genetic composition of a population through random events such as mating and production of offspring*

D. **bottleneck effect—***a reduction in genetic diversity because of a reduction in size*

E. **founder effect—***change in genetic makeup of a population due to a small number of colonizing individuals*

MODULE 16: Speciation and the Pace of Evolution

I. Speciation – focus on allopatric vs. sympatric

A. **speciation**—adaptation to the point of becoming a new species

1) through *natural selection* and *mutations*

2) through **reproductive isolation**

3) new species are formed by *gradual modification* of existing species

B. **Allopatric speciation**—*speciation as a result of geographic isolation*

C. **Sympatric speciation**—*speciation without geographic isolation*

*** See p. 8 for diagram. ***

D. Darwin's finches: beak specialization for different tasks

Galápagos background info (from Galapagos.org and Galapagos.com)

The Galápagos Islands are located on the equator, 600 miles from the coast of Ecuador. The climate is considered to be cool and sub-tropical, with hot, arid coastal zones and cooler, humid highland areas. The highlands receive moisture year-round, which supports lush vegetation. Galápagos gets an average of ten inches of rainfall per year.

Islands and their features:

- Bartolome—lava tubes, Pinnacle Rock; penguins
- Espanola—albatross, sea lions…
- Fernandina— pristine; rare species; flightless cormorants (fish-eating birds), marine iguanas…
- Floreana—Devil's Crown crater; flamingoes, sea turtles…
- Isabela—largest island; active volcanoes; marine iguanas, flightless cormorants, dolphins…
- North Seymour—nesting site; forests; marine iguanas, sea lions…
- Rabida—red beaches; nesting site; pelicans, flamingoes…
- San Cristobal—tourist port; birds and other wildlife…
- Santa Cruz (research center)—tortoises, iguanas, birds…
- Santa Fe—coves; sea turtles, manta rays, cacti; marine iguanas…
- Santiago—tide pools on the equator; lava fields; fur seals; feral goats
- South Plaza—cliffs; sea lions, birds, iguanas…
- Tower—birding island

II. Evolutionary pace

A. rapid evolution by natural selection

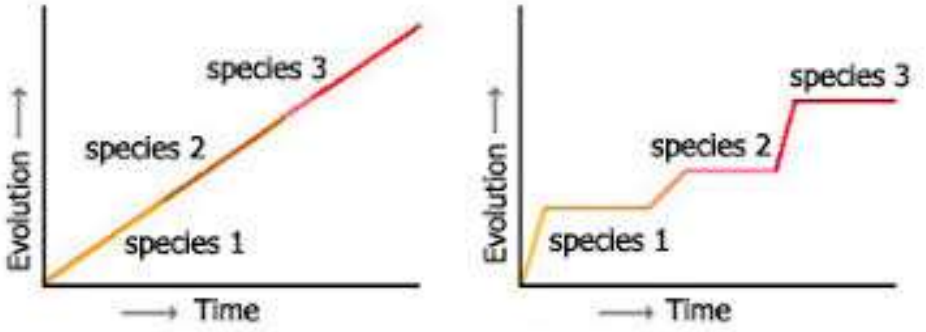
B. very rapid evolution by artificial selection

C. views on pace

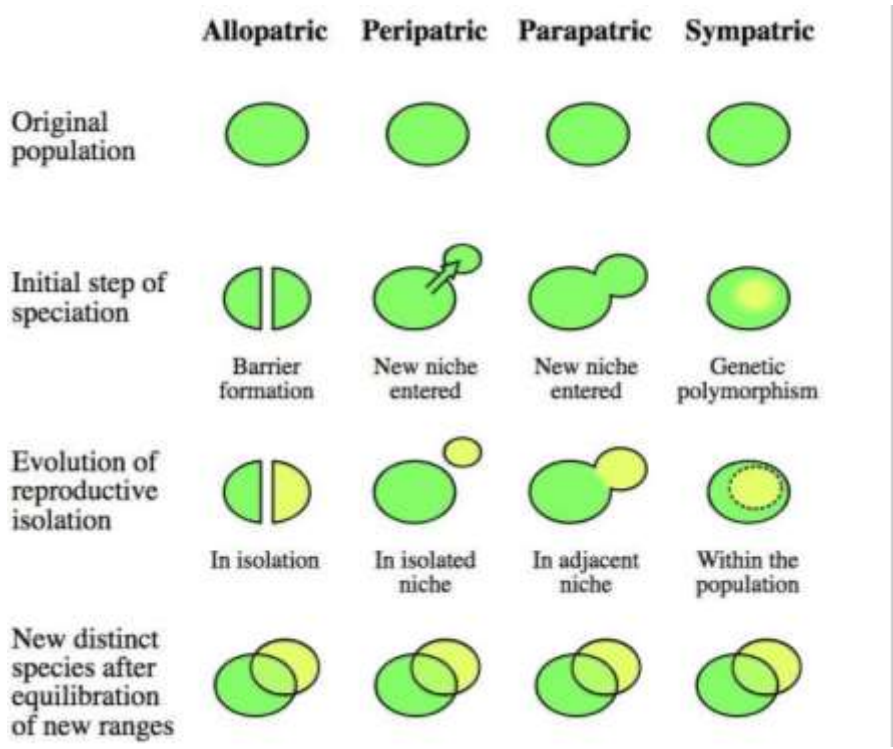
1) *gradualism* (old view)

2) *punctuated equilibrium*—alternating periods of stasis and rapid change

GRADUALISM PUNCTUATED EQUILIBRIUM



Source: McGill



Source: National Geographic

MODULE 17: Evolution of Niches and Species Distributions

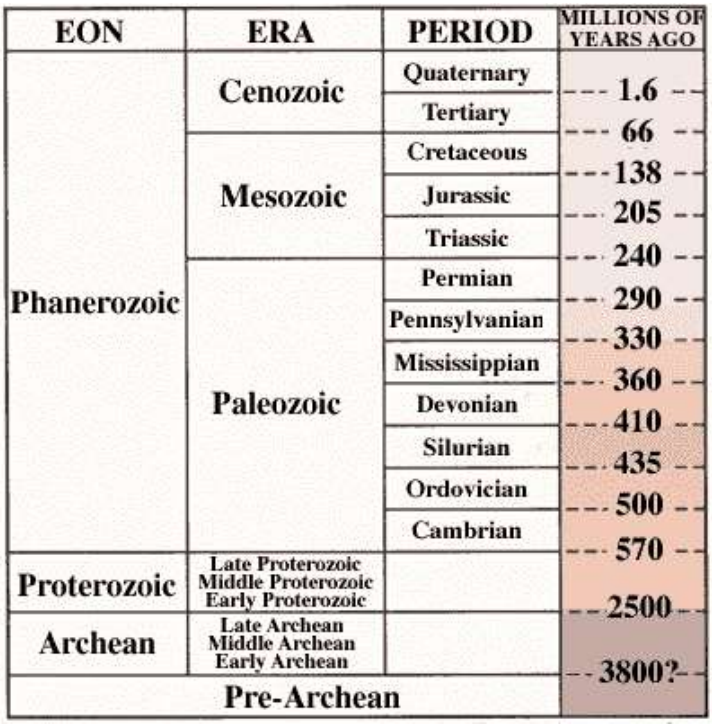
I. Niches
- A. *niche*—the role or job an organism has in its environment
- B. **fundamental niche**—*the abiotic conditions under which an organism can survive and reproduce itself*
- C. **realized niche**—*the abiotic and biotic conditions under which an organism actually lives*
- D. **niche generalists**—organisms that can live in a wide range of niches/conditions
- E. **niche specialists**—*organisms that are restricted to live in a very narrow range of conditions or feed upon a small amount of species*
- F. **distribution**—*areas in which a species lives*

II. Species Distribution and environmental change
- A. Terrestrial ecosystem abiotic factors: temperature, precipitation, humidity, physical boundaries (natural and human made), nutrient availability, soil structure, soil aeration, predation, atmospheric gases, altitude, pollution, weather events…
- B. Aquatic ecosystem abiotic factors: salinity, pH, sunlight availability, temperature, physical boundaries (natural and human made), water currents, pollution, TDS, DO…

III. Species Extinction
- A. **extinction**—*loss of a species worldwide*
- B. **mass extinction**
  1) a large amount of species dying out in a relatively short time
  2) a *biotic crisis*: a drastic change in the biodiversity and abundance of organisms
  3) six mass extinctions:

a) Paleozoic Era, End Ordovician Period, 444 million years ago, 86% of species lost
b) Paleozoic Era, Late Devonian Period, 375 million years ago, 75% of species lost
c) Paleozoic Era, End Permian Period, 251 million years ago, 96% of species lost
d) Mesozoic Era, End Triassic Period, 200 million years ago, 80% of species lost
e) Mesozoic Era, end of Cretaceous Period, 65 million years ago, 76% of all species lost
f) Cenozoic Era, "Holocene extinction," Present time. *Anthropogenic causes.*

BASIC GEOLOGIC TIME SCALE



Source: Wikibooks

****** IMPORTANT NOTE: When you are reviewing past FRQs, be sure you know updated information about a species' national status. Some of the scoring rubric information online is outdated and therefore incorrect. ******

B. **IUCN Red List search** **https://www.iucnredlist.org/**
   1) IUCN codes: NE (not evaluated); DD (data deficient)
   2) IUCN listing progression: LC → NT → VU → EN → CR →EW → EX

C. species information, quotes from http://wdfw.wa.gov/
   (species can have a different designation nationally vs. state-wide)
   1) **species of least concern (LC)**
      a) *the wildlife is abundant and is likely to survive in the wild*
      b) native wildlife may be prescribed as least concern wildlife even if the population size or distribution of the wildlife has declined

c) there is insufficient information about the wildlife to conclude whether the wildlife is common or abundant or likely to survive in the wild
d) examples: Eastern cottontail rabbit, brown bear, bald eagle, dolphin gull, brown pelican

[3]

2) *species of concern*

"include those species listed as State Endangered, State Threatened, State Sensitive, or State Candidate, as well as species listed or proposed for listing by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service."

3) *monitor species* are not considered Species of Concern but are monitored for status and distribution

4) *candidate species*

"Include fish and wildlife species that the Department will review for possible listing as State Endangered, Threatened, or Sensitive. A species will be considered for designation as a State Candidate if sufficient evidence suggests that its status may meet the listing criteria..."

5) *sensitive species*

"Any wildlife species native (to the area) that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range (within the area) without cooperative management or removal of threats."

6) **near threatened / threatened species (NT or T)** *have populations in a rapid decline*

definition: "Any wildlife species native (to the area) that is likely to become an endangered species within the foreseeable future throughout a significant portion of its range (within the area) without cooperative management or removal of threats."

Examples: bee hummingbird, Albacore tuna, jaguar, Ivory coast wart frog

7) **vulnerable (VU)**
   a) *faces a high risk of extinction in the medium-term*
   b) examples: African elephant, Giant panda, polar bear, cheetah, Blue marlin, loggerhead turtle, American manatee

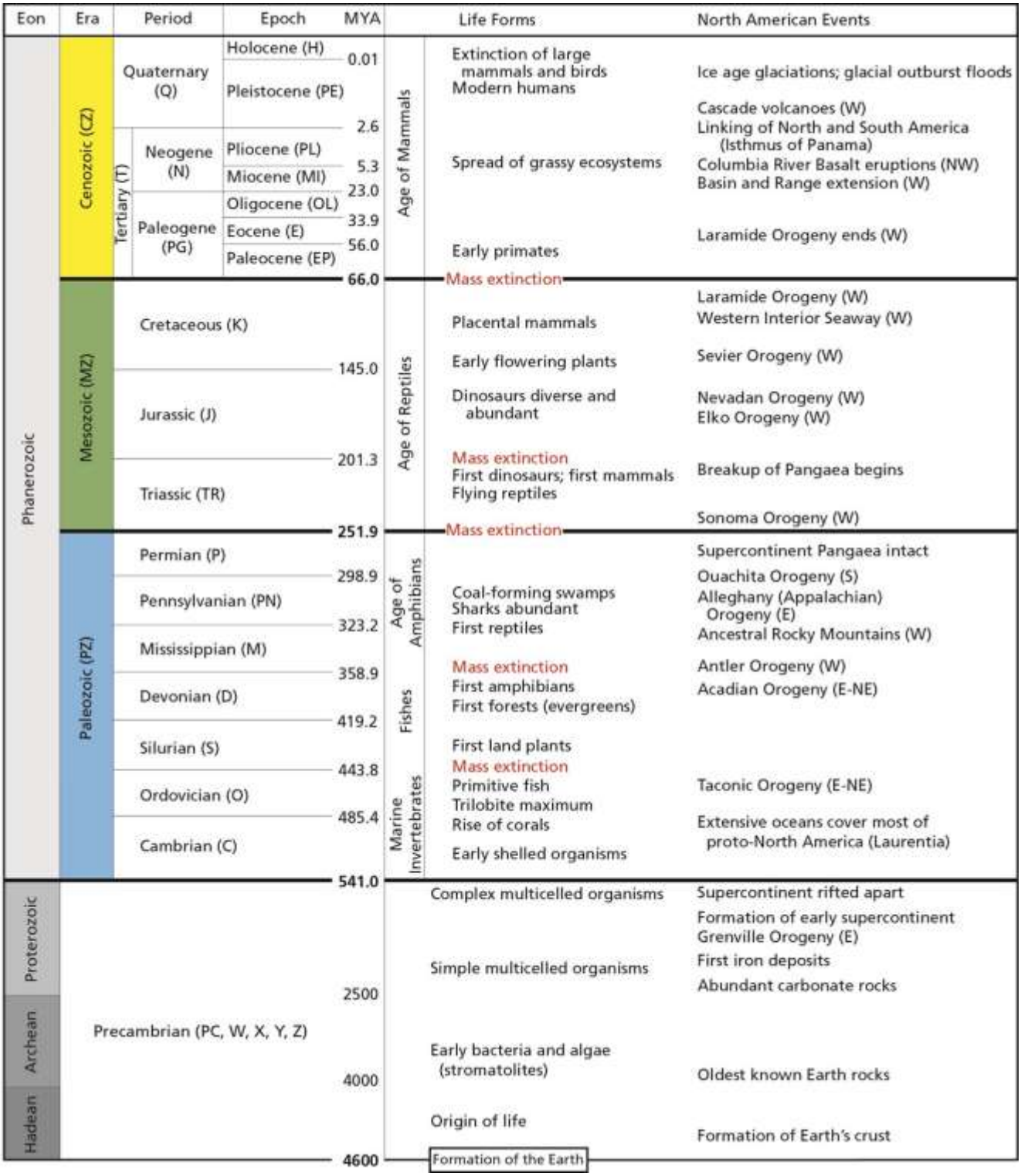
8) **endangered species (EN)**
   a) *have populations nearing the estimated critical number*
   b) "seriously threatened with extinction throughout all or a significant portion of its range"
   c) faces a very high risk of extinction in the near future
   d) examples: bluefin tuna, whooping crane, blue whale, Beebe's rocket frog, lion-tailed Macaque

9) **critically endangered species (CR)**
   a) *faces an extremely high risk of extinction in the immediate future*
   b) examples: black rhino, click beetle, Sumatran orangutan, Florida panther, Chinese alligator

10) **extinct in the wild (EW)**
   a) captive individuals survive, but there is no free-living, natural population
   b) examples: Alagoas curassow bird, Hawaiian crow, Wyoming toad

11) **extinct (EX)**
   a) the last remaining member of the species had died, or is presumed beyond reasonable doubt to have died
   b) examples: Dodo bird, passenger pigeon, wooly mammoth, Steller's sea cow

GEOLOGIC TIME SCALE from NPS.gov



NOTE: orogeny = mountain formation