What is Hardy Weinberg Theory?

Equations that enable us to determine how much a population is evolving from generation to generation.

“**Hardy-Weinberg equilibrium**”: Refers to an idealized, non-evolving population. Five characteristics:

Characteristics of a non-evolving population:

1. Large size (no genetic drift)
2. Random mating (no sexual selection)
3. Stable environment (no natural selection)
4. No immigration/emigration (no gene flow)
5. No mutations.

No real population is in HW equilibrium.

Hardy-Weinberg Equations

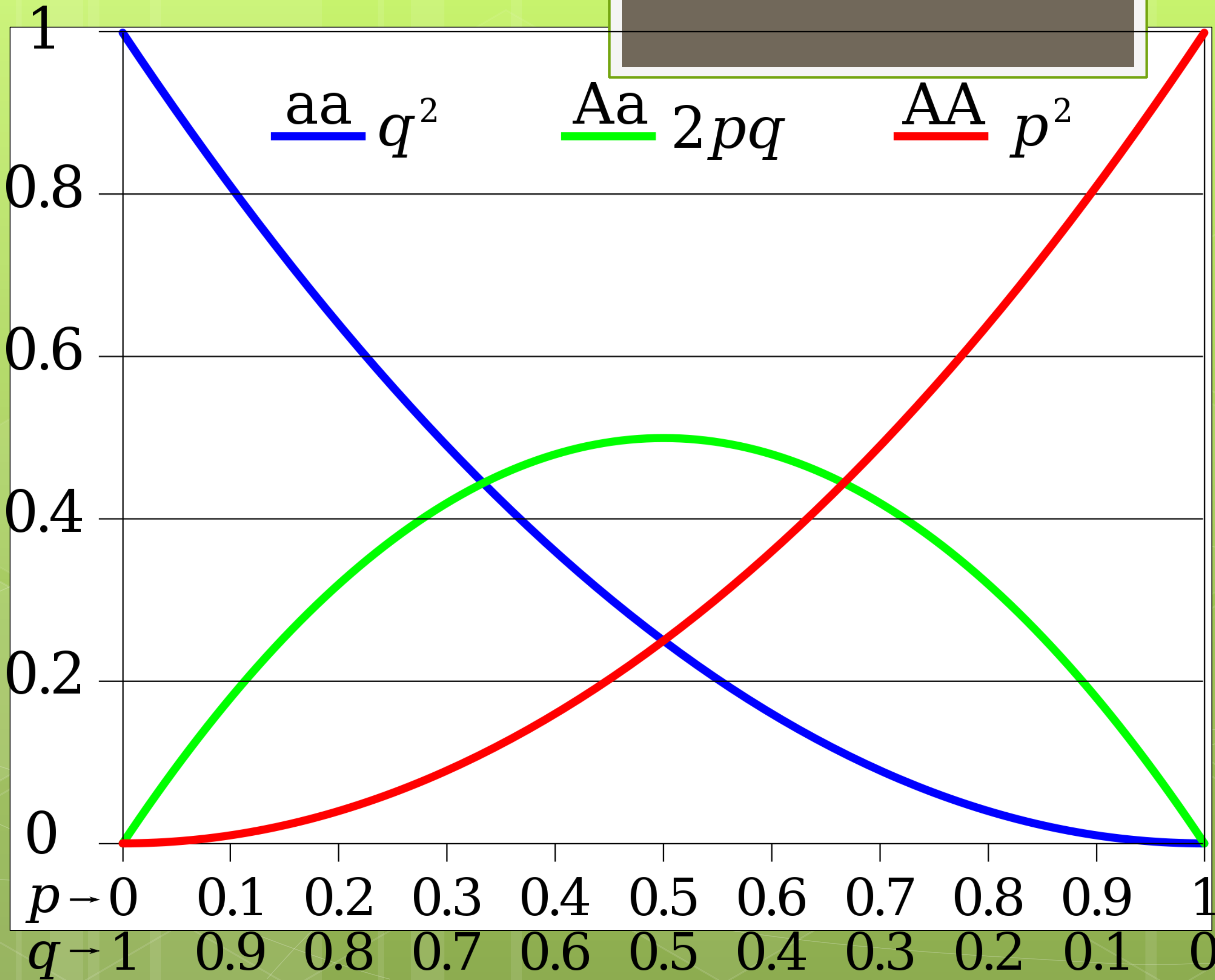
For a trait controlled by two alleles, where p is the dominant allele and q is the recessive allele:

Gene Frequency:

$$p + q = 1$$

Genotype Frequency:

$$p^2 + 2pq + q^2 = 1$$



aa q^2
Aa $2pq$
AA p^2
1
0.8
0.6
0.4
0.2
0
$p \rightarrow$ 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
$q \rightarrow$ 1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0

Sample Problem

In pea plants, the allele for purple flowers is dominant to the allele for white flowers. If 99% of the plants in the population have purple flowers, determine the percentage of heterozygotes in the population.

Uses of HW Theory

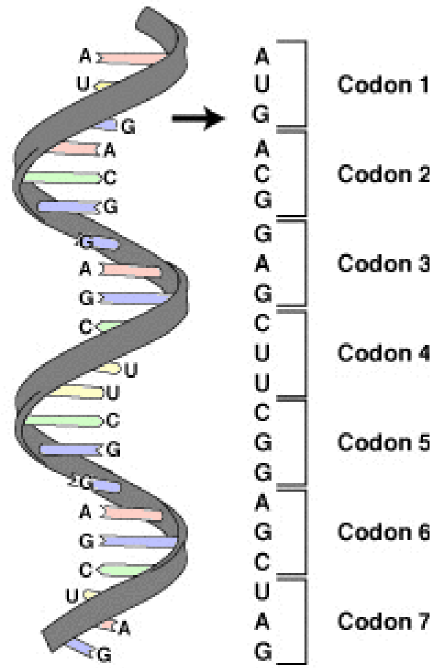
To determine how a population is evolving from generation to generation.

To help to determine which evolutionary pressures are affecting a population more/less.

1. Evidence of Common Ancestry

1.5 Organisms share many conserved core processes and features that evolved and are widely distributed among many organisms today

The Universal Genetic Code



RNA

Ribonucleic acid

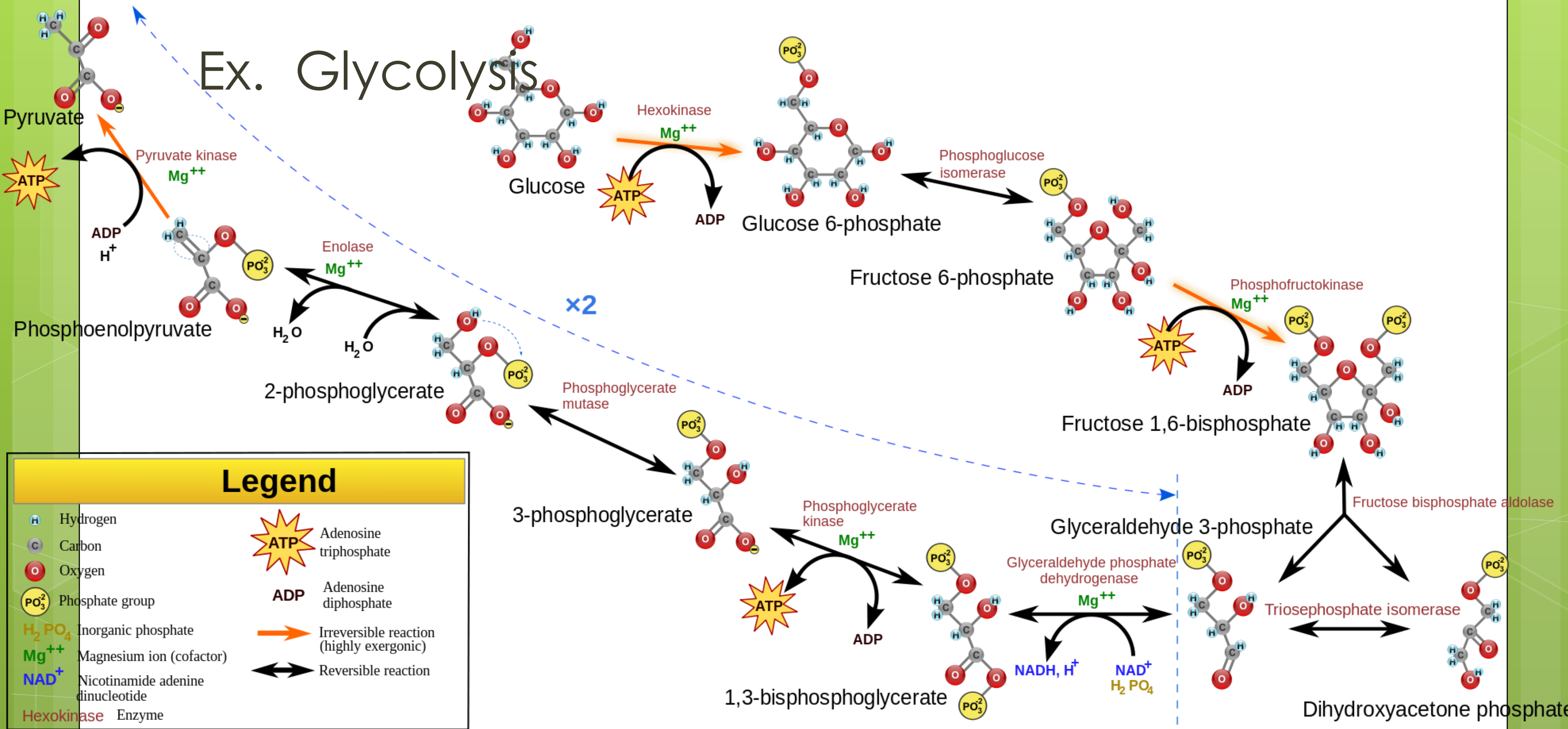
1st base

2nd base	U		C		A		G		3rd base
U	UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine	U
	UUC	Phenylalanine	UCC	Serine	UAC	Tyrosine	UGC	Cysteine	C
	UUA	Leucine	UCA	Serine	UAA	Stop	UGA	Stop	A
	UUG	Leucine	UCG	Serine	UAG	Stop	UGG	Tryptophan	G
C	CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine	U
	CUC	Leucine	CCC	Proline	CAC	Histidine	CGC	Arginine	C
	CUA	Leucine	CCA	Proline	CAA	Glutamine	CGA	Arginine	A
	CUG	Leucine	CCG	Proline	CAG	Glutamine	CGG	Arginine	G
A	AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine	U
	AUC	Isoleucine	ACC	Threonine	AAC	Asparagine	AGC	Serine	C
	AUA	Isoleucine	ACA	Threonine	AAA	Lysine	AGA	Arginine	A
	AUG	Methionine (Start)	ACG	Threonine	AAG	Lysine	AGG	Arginine	G
G	GUU	Valine	GCU	Alanine	GAU	Aspartic Acid	GGU	Glycine	U
	GUC	Valine	GCC	Alanine	GAC	Aspartic Acid	GGC	Glycine	C
	GUA	Valine	GCA	Alanine	GAA	Glutamic Acid	GGA	Glycine	A
	GUG	Valine	GCG	Alanine	GAG	Glutamic Acid	GGG	Glycine	G

Nonpolar, aliphatic   Polar, uncharged   Aromatic   Positively charged   Negatively charged

Common Metabolic Pathways

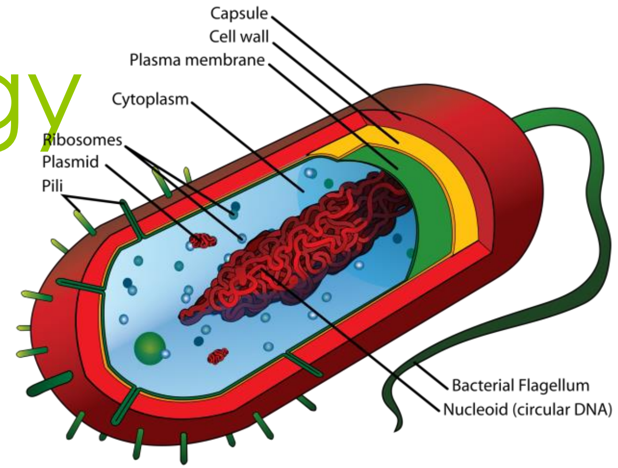
Ex. Glycolysis



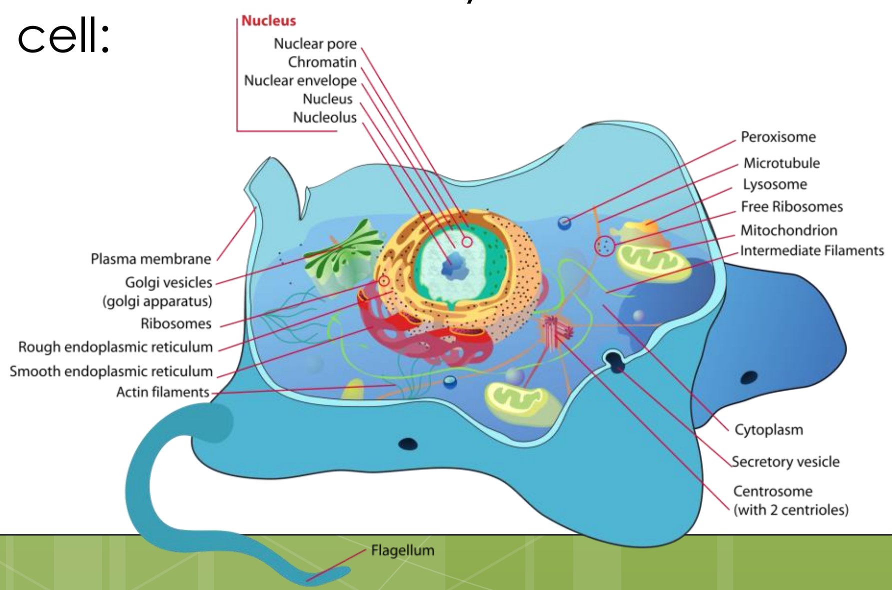
Cellular Morphology

Note: Not to scale.

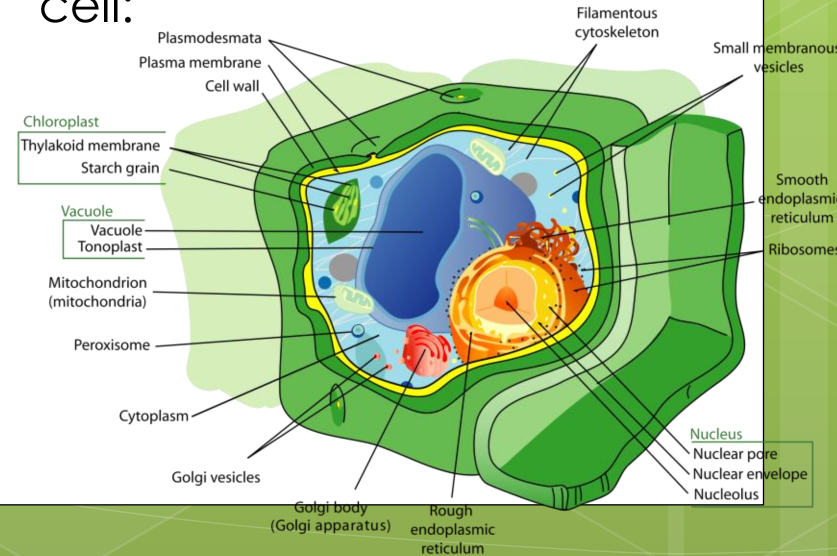
Prokaryotic Cell:



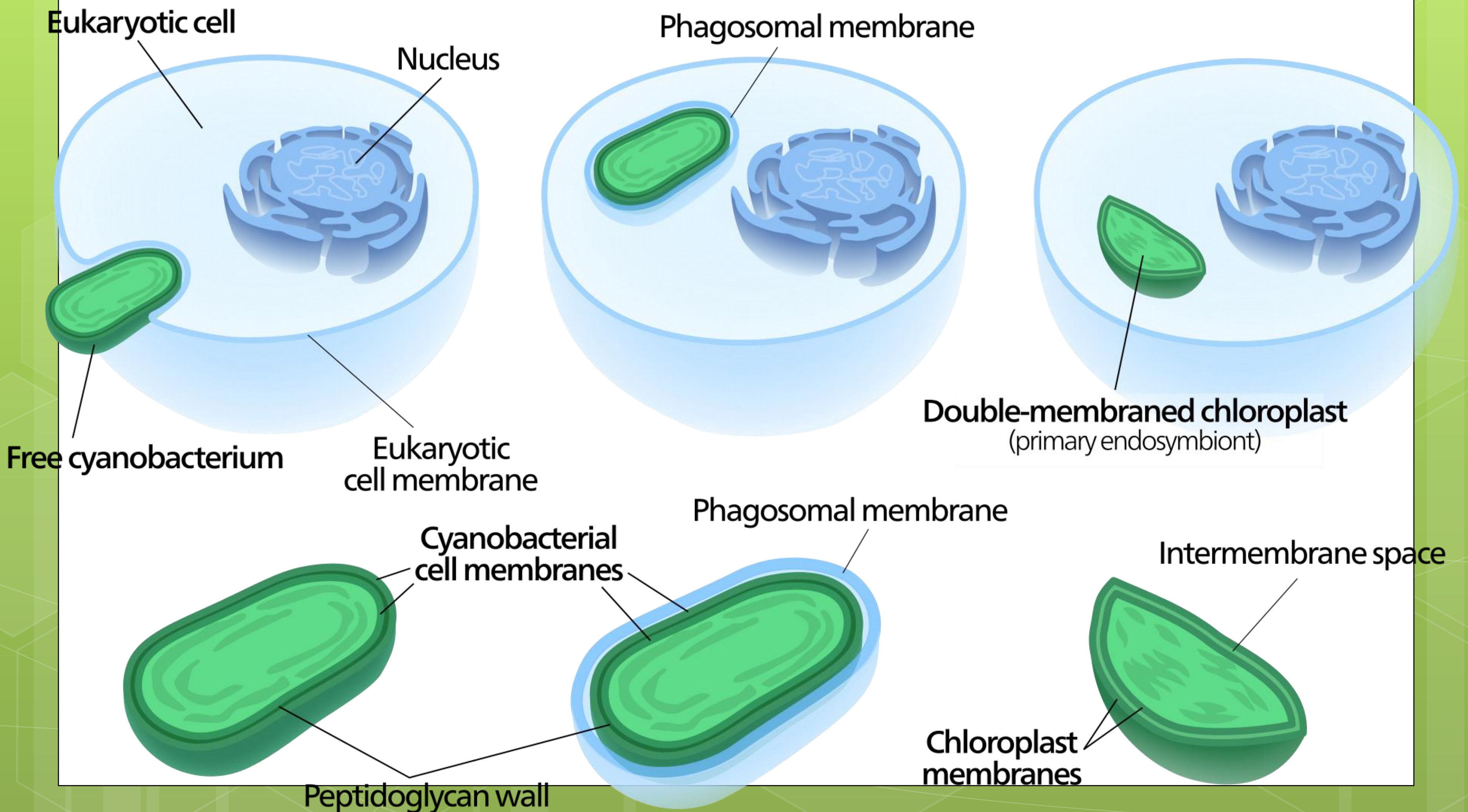
"Animal-like" eukaryotic cell:



"Plant-like" eukaryotic cell:



Endosymbiosis



1. Phylogeny

1.6: Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.

Cladograms

Diagrams that group items together based on the number of common characteristics.

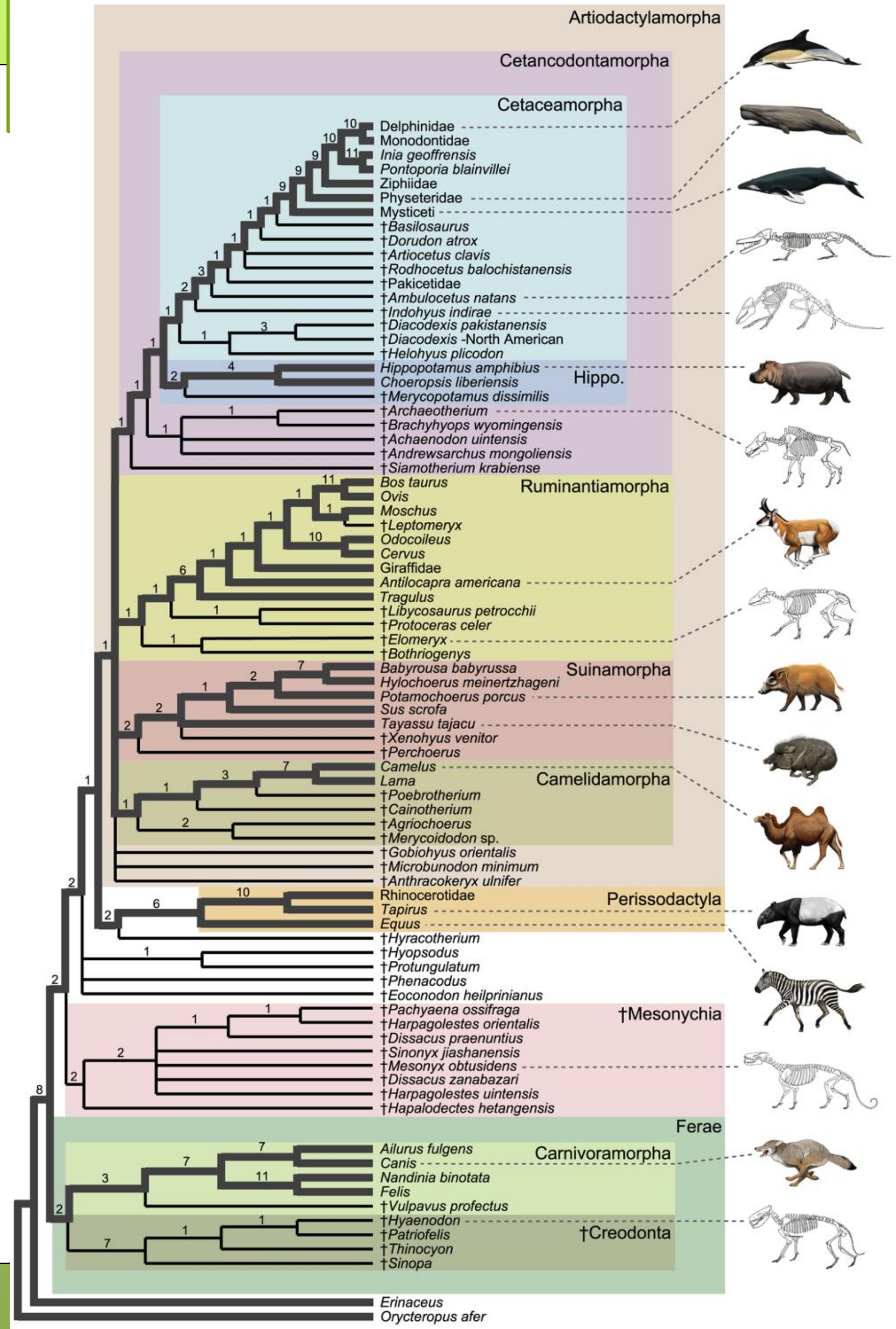
1. Determine number of shared characteristics.
2. Arrange items as a tree showing most commonality possible

Phylogenetic Tree

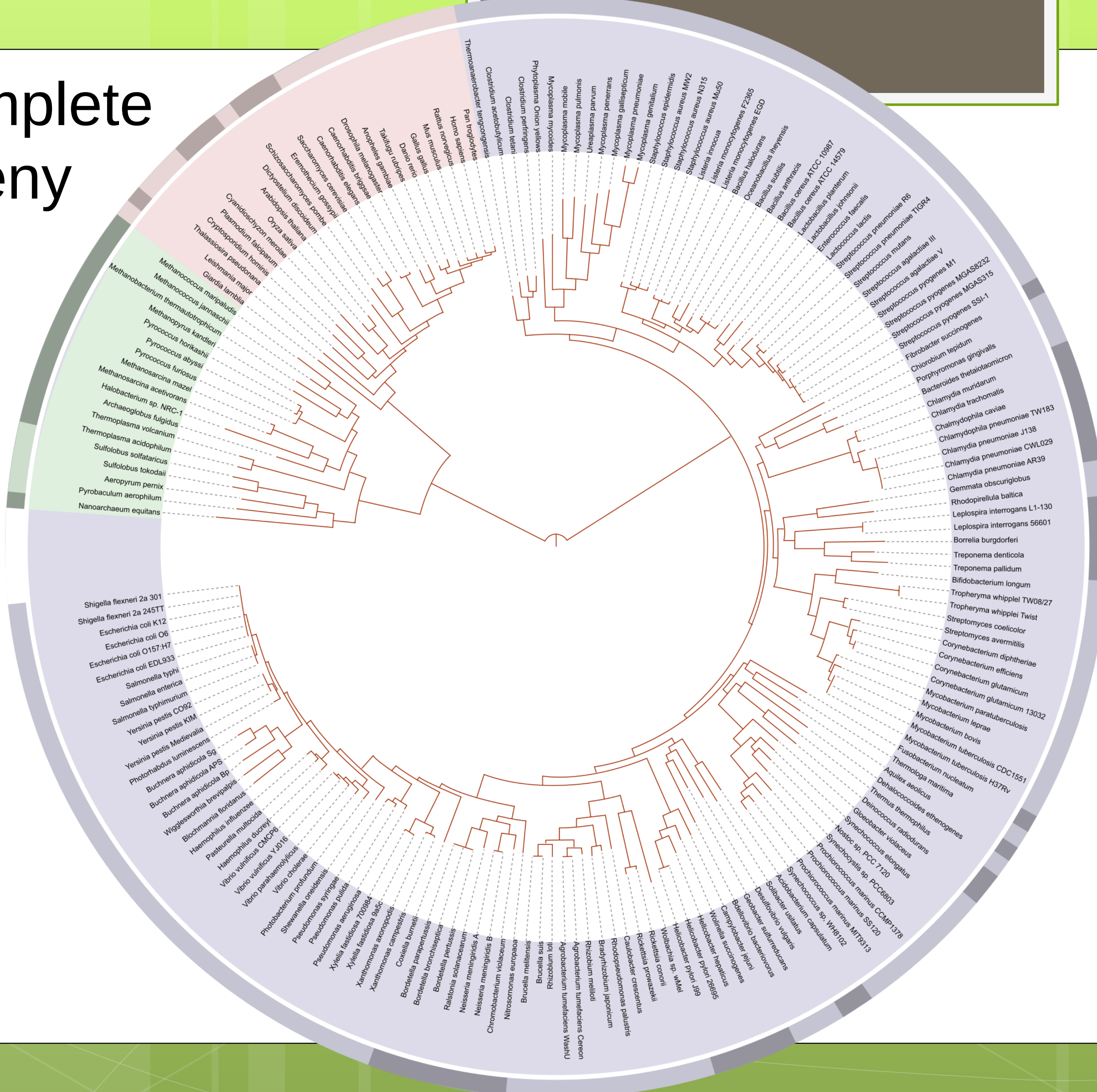
A cladogram that represents evolutionary relationships. Use two types of data:

1. **Shared Derived Characters**: Physical traits that represent evolutionary history (homologous structures).
2. **DNA/Protein sequence Data**: Differences in sequences accumulate as species evolve away from each other.

Ex. Vertebrate Phylogeny.



Ex. Complete Phylogeny



Phylogenetic Tree Construction

1. Determine similarities among organisms (character table works well).
2. Arrange organisms in a tree diagram showing simplest possible evolution.

Maximum parsimony: All else being equal, a trait is assumed to evolve once and be present in all descendants

SKILL: Create a tree-Selected Vertebrates

Character Table:

Animal	Opposable Thumb	4-chamber heart	Amniotic egg	lungs	Spinal column
Chimpanzee	1	1	1	1	1
Mouse	0	1	1	1	1
Turtle	0	0	1	1	1
Frog	0	0	0	1	1
Fish	0	0	0	0	1
Lamprey	0	0	0	0	0

Trees are Hypotheses

Continual revision:

As more data is gathered, the phylogenetic relationships among organisms are continually revised.

Role of computers:

Computer analysis is needed to determine the similarities in large amounts of DNA/protein sequence information.

1. Speciation Concepts

1.7: Speciation and extinction have occurred throughout the Earth's history.

What is a species?

“**Biological Species**”: A group of organisms that are capable of successfully reproducing.

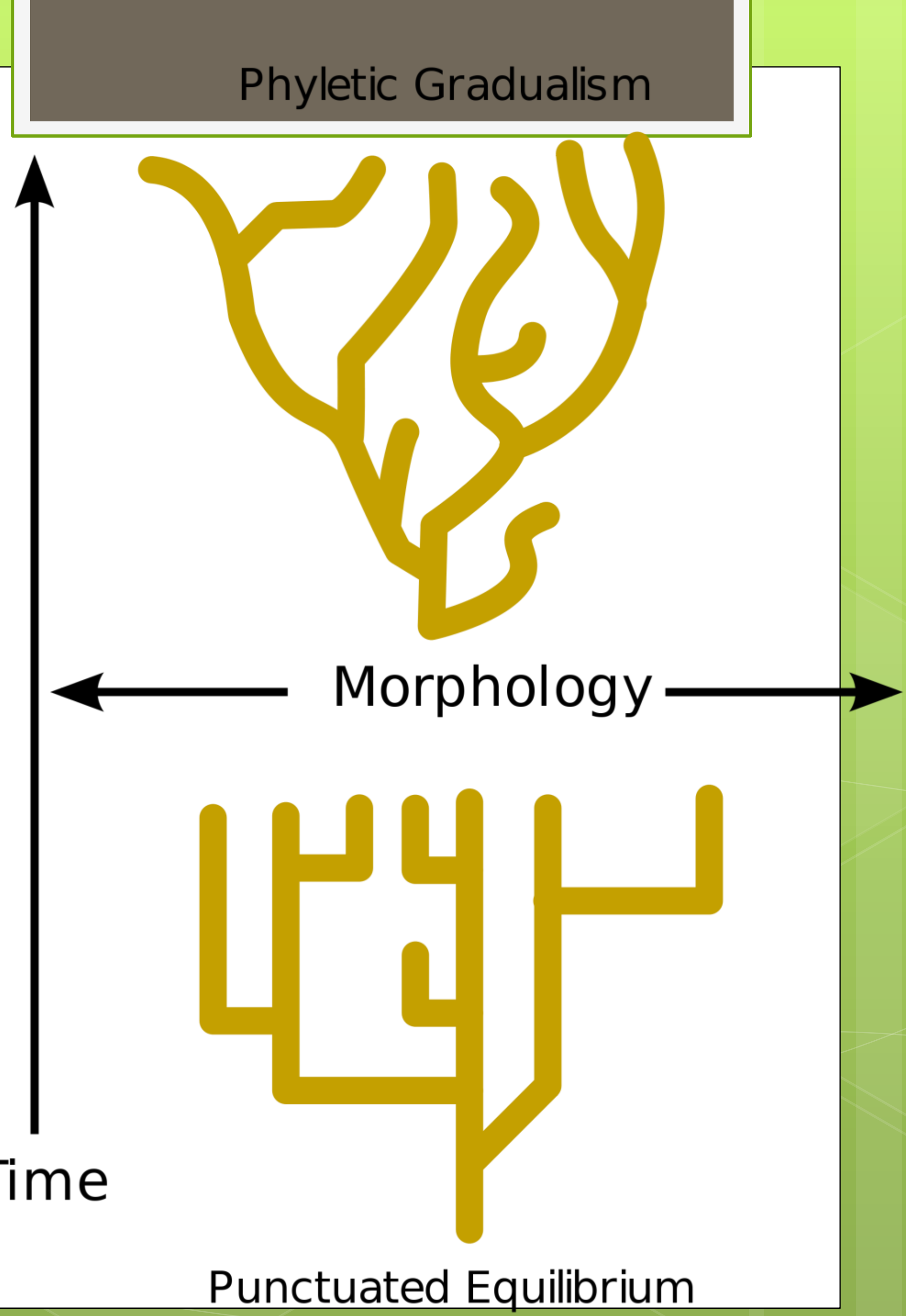
It’s testable, but simplistic.

And it is limited in application.

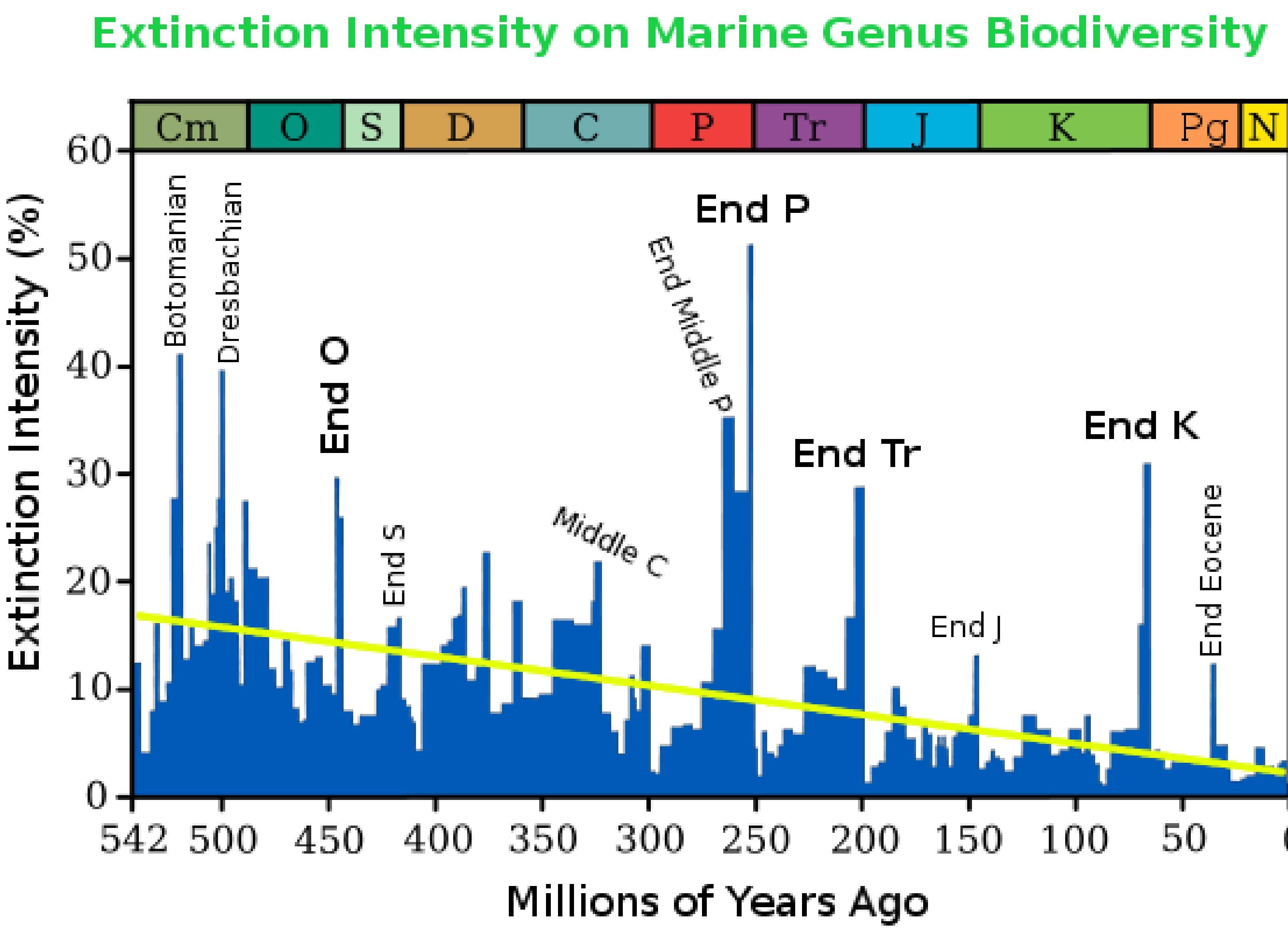
Speciation Rate

Gradualism: species are the product of slowly accumulating, small evolutionary changes.

Punctuated equilibrium: species undergo long periods of very little change, followed by rapid, large evolutionary changes.



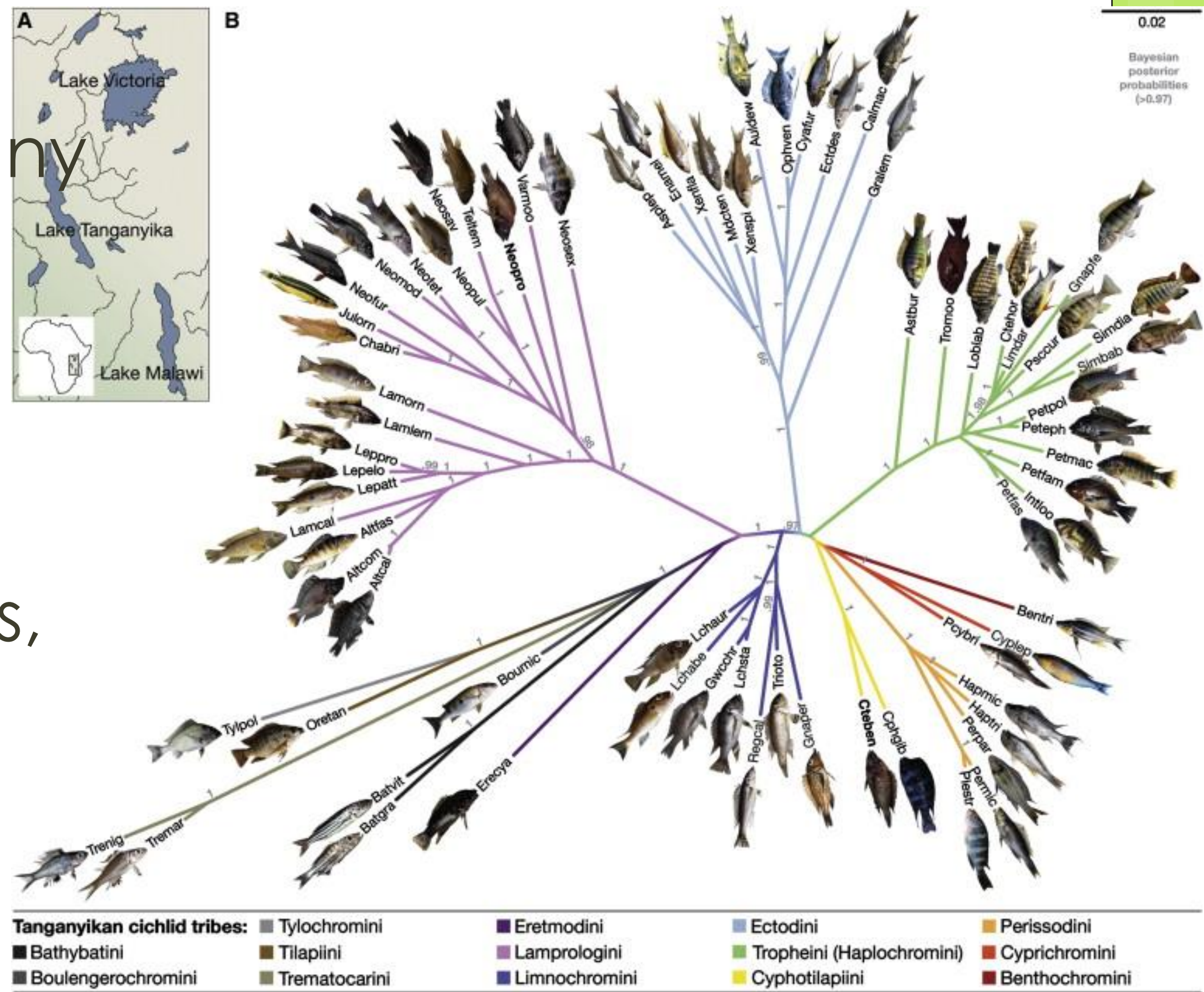
Ex. Major Extinctions.



Adaptive Radiation

One species evolves in to many species that occupy open niches.

Ex. Lake Cichlids, Mammals, Galapagos Finches.



1. Speciation process

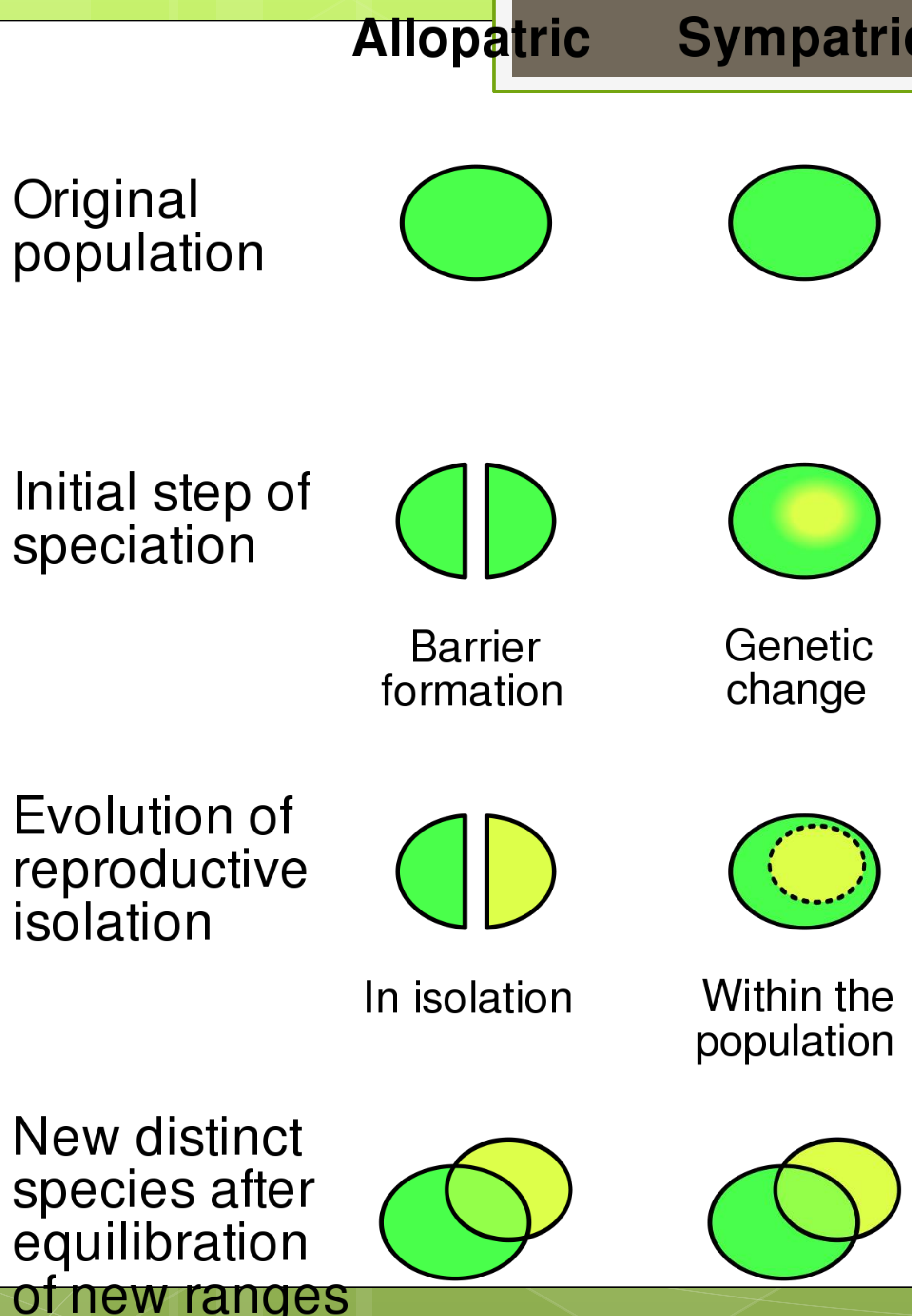
1.8: Speciation may occur when two populations become reproductively isolated from each other.

Reproductive Isolation

Speciation occurs when a population can no longer interbreed with any other population.

Allopatric: Happens due to physical separation.

Sympatric: Happens while occupying the same area.


Allopatric
Sympatric
Original population
Initial step of speciation
Barrier formation
Genetic change
Evolution of reproductive isolation
In isolation
Within the population
New distinct species after equilibration of new ranges

Species Barriers

Pre-Zygotic: **Post-Zygotic:**

Physical Reduced Viability

Temporal Reduced Fertility

Behavioral Hybrid Breakdown

Mechanical

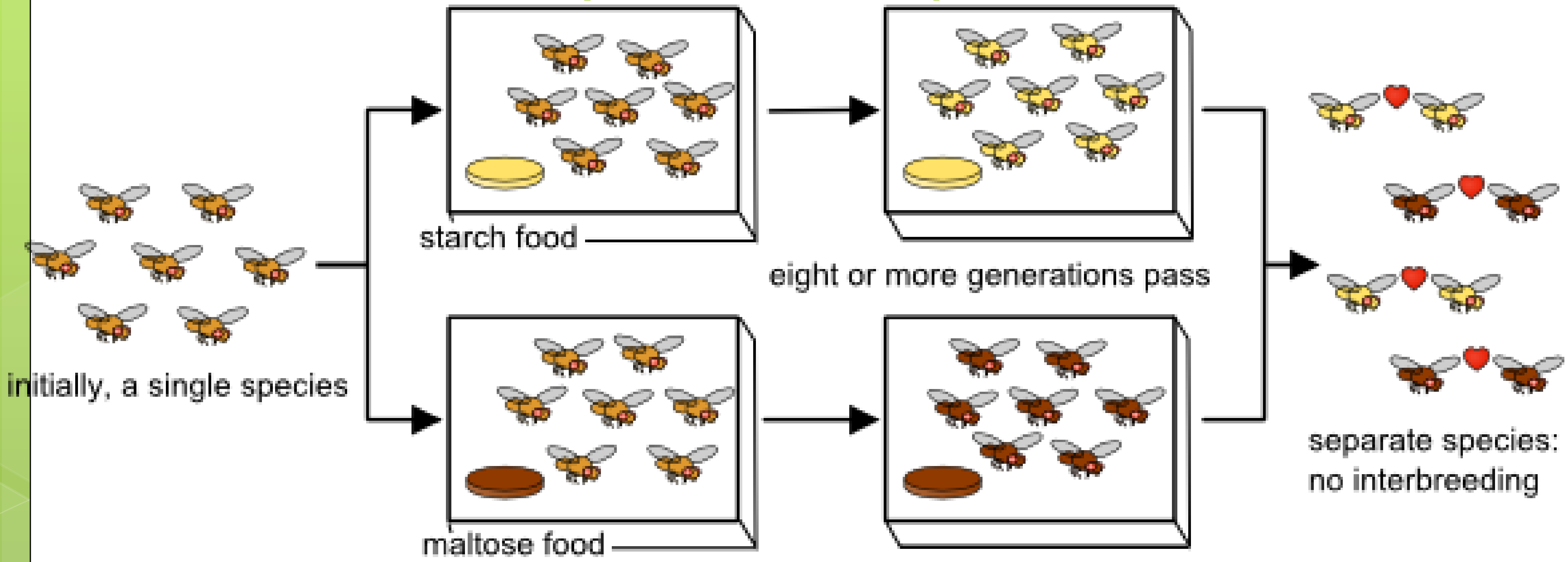
Chemical

Ex. Mules

Ex. Apples


ORGANICALLY GROWN IN CALIFORNIA
Fuji Apples
$2.29 LB
sustainability
ORGANIC
Red D'Anjou Pears

Ex. Fruit Fly Food Speciation.



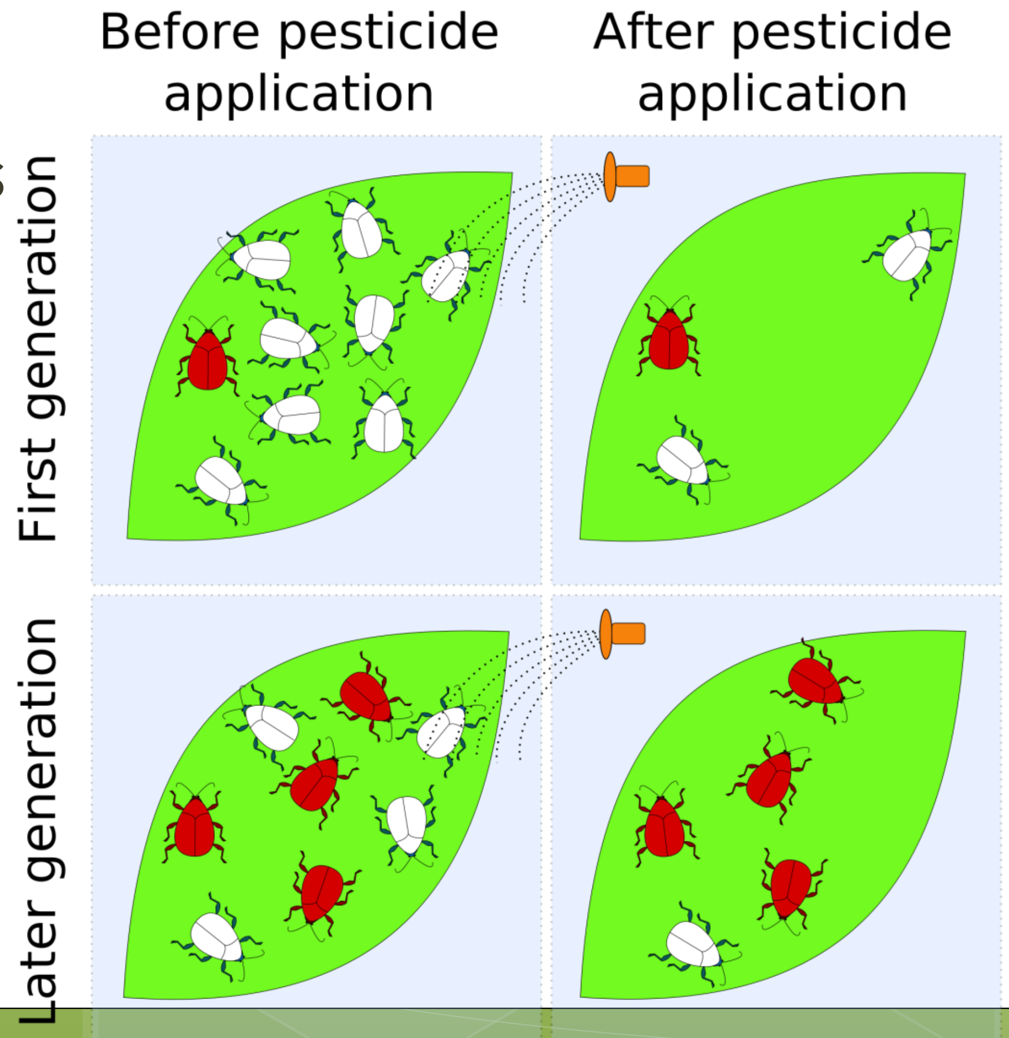
1. Ongoing evolution of organisms

1.9 Populations of Organisms Continue to Evolve

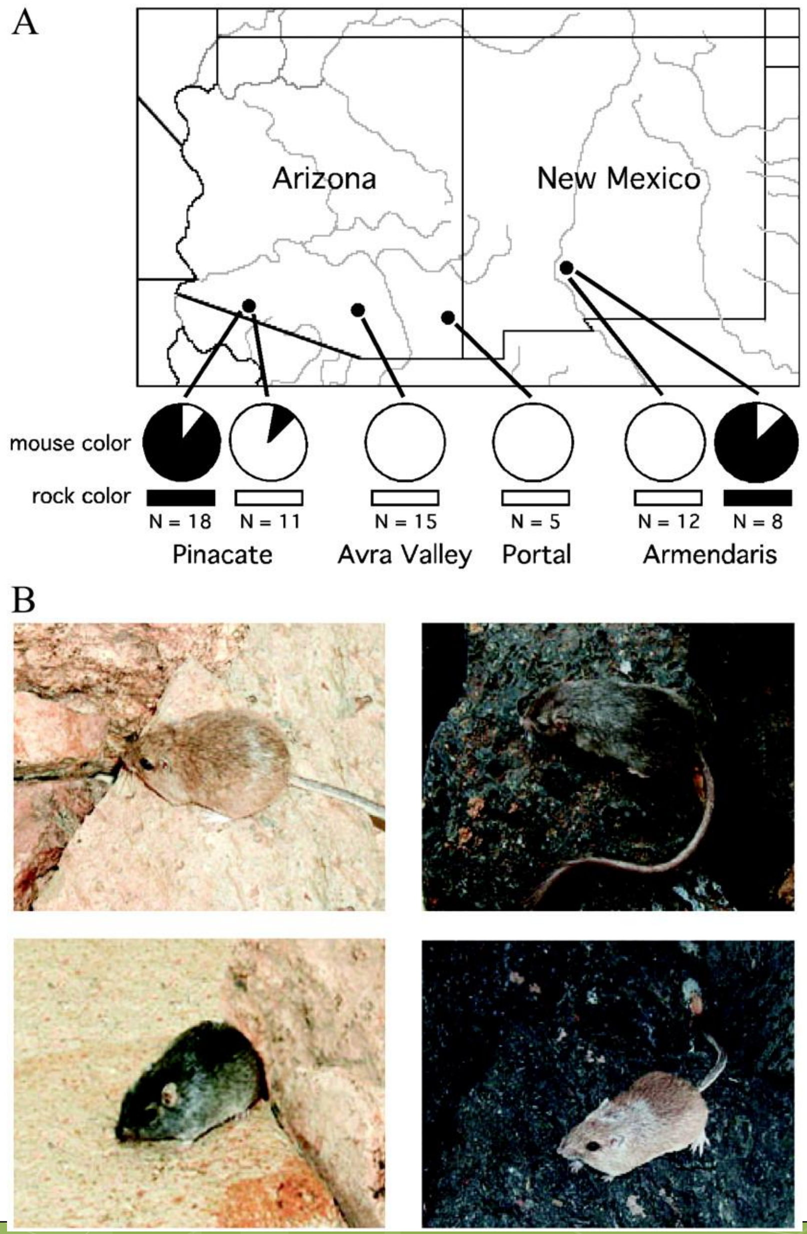
Evolution is Ongoing

Evolution continues to happen.

Ex. Pesticide Resistance

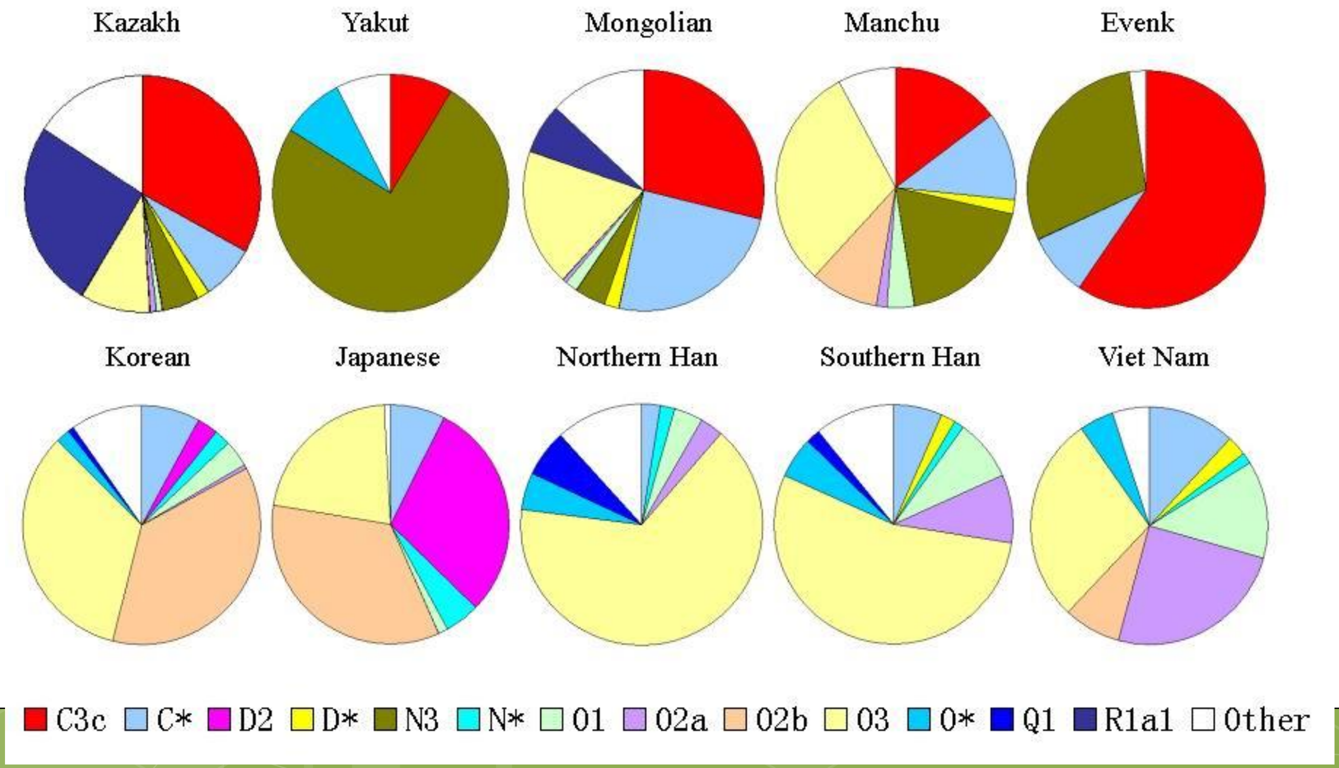


Ex. Rock Pocket Mouse



Analysis of Evolution

Mathematical modeling (e.g. HW Equilibrium) and genetic analysis can be used to investigate evolution as it occurs in real-time over generations.



1. Origin of life

1.10: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence.

Origin Hypotheses

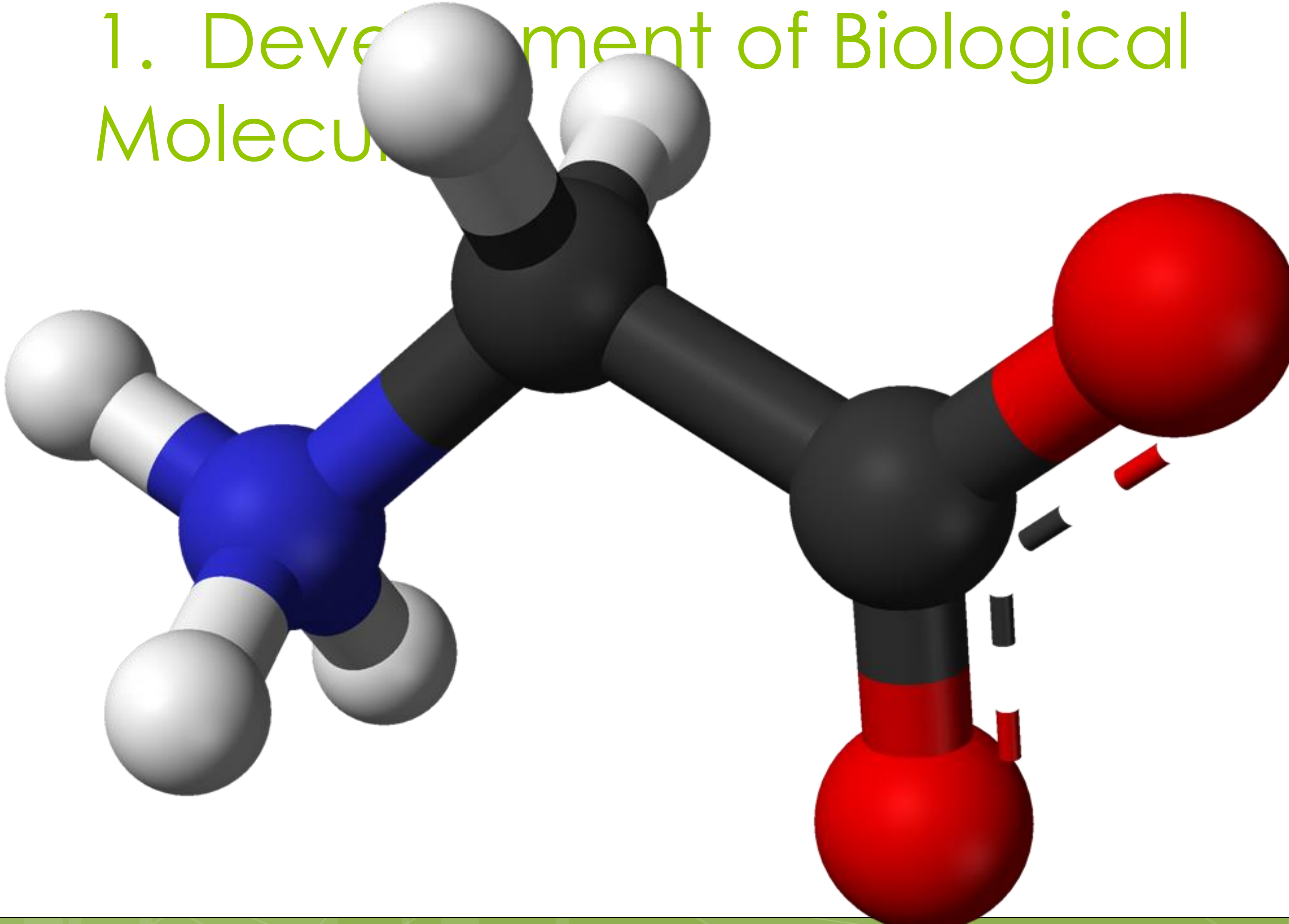
Hypotheses must be testable. Many thoughts about the origin of life are not testable.

Two major hypothesis for life on Earth.

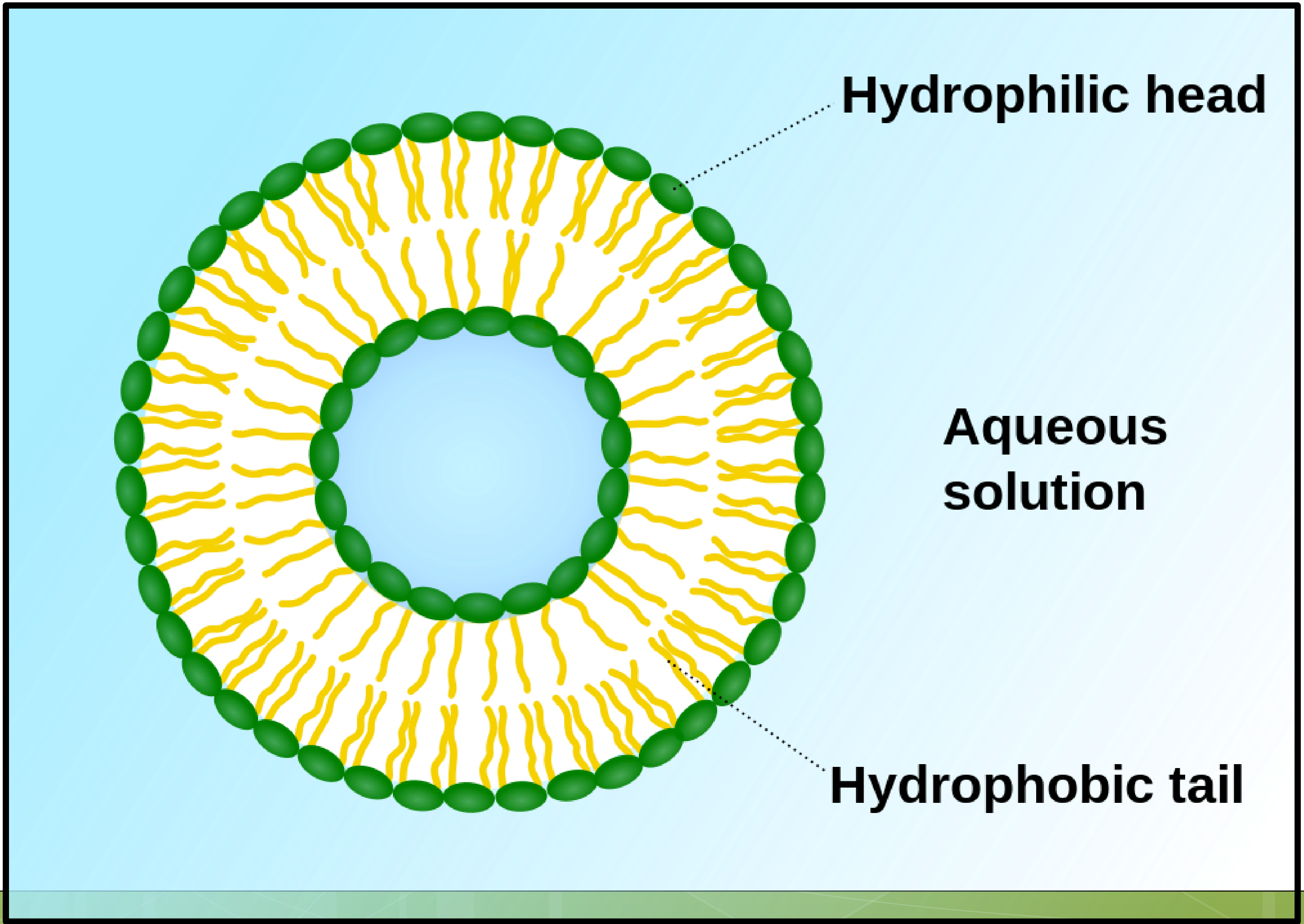
1. **Panspermia**: Life from extraterrestrial life.

1. **Abiogenesis**: Life from non-life. Requires 4 major milestones to occur.

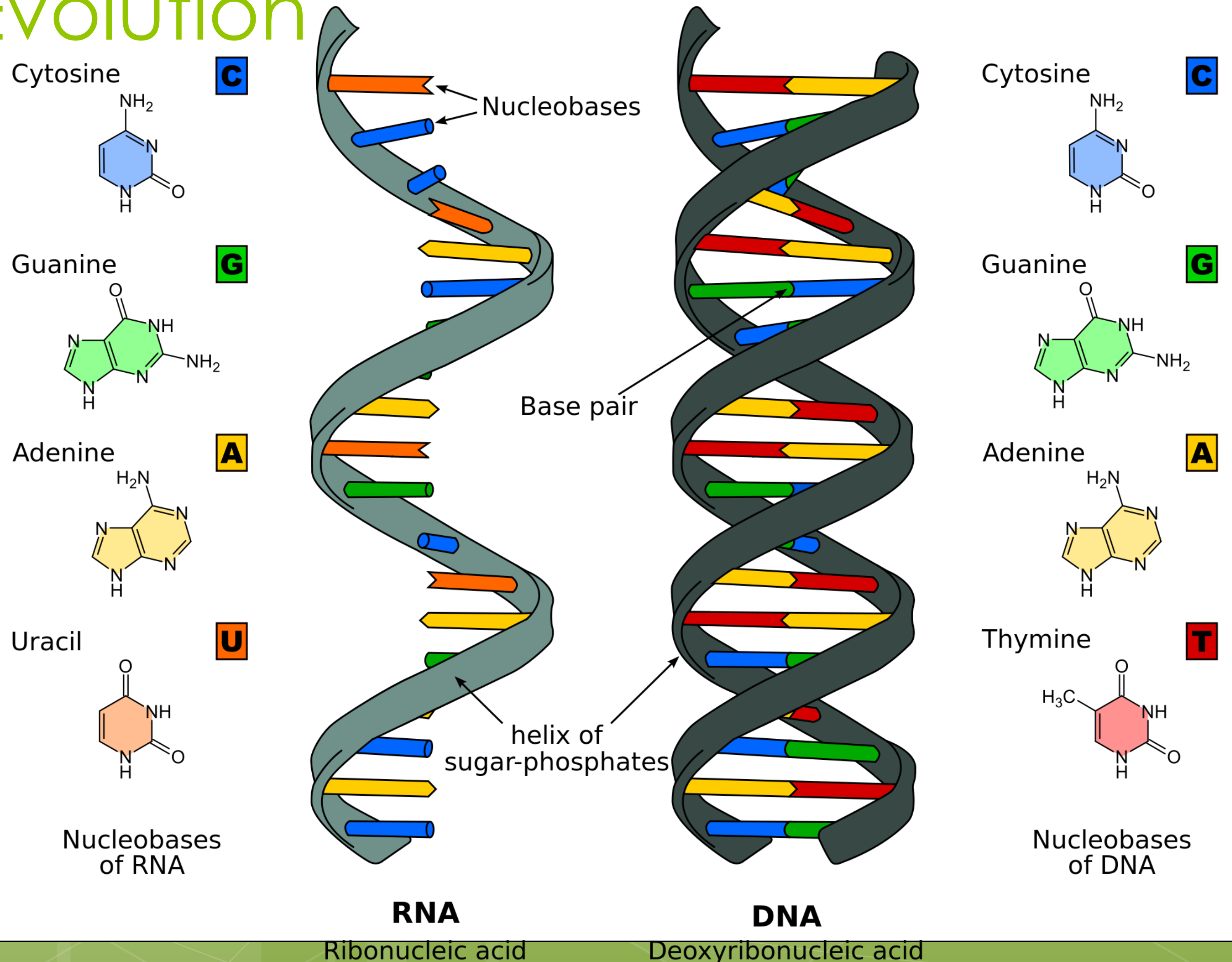
1. Deve ment of Biological Molecu

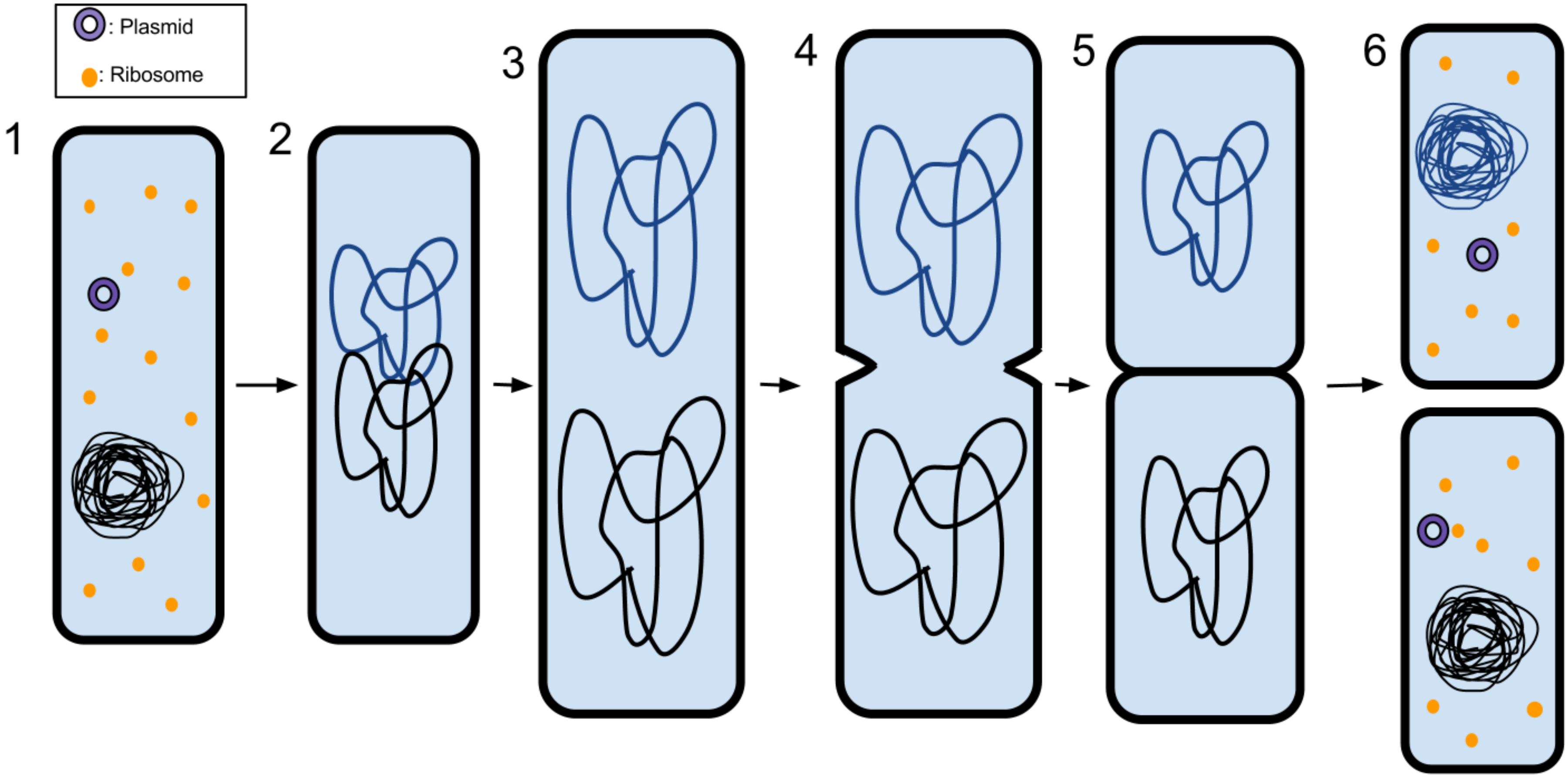


2. Development of Proto-cells



3. Information Molecule Evolution

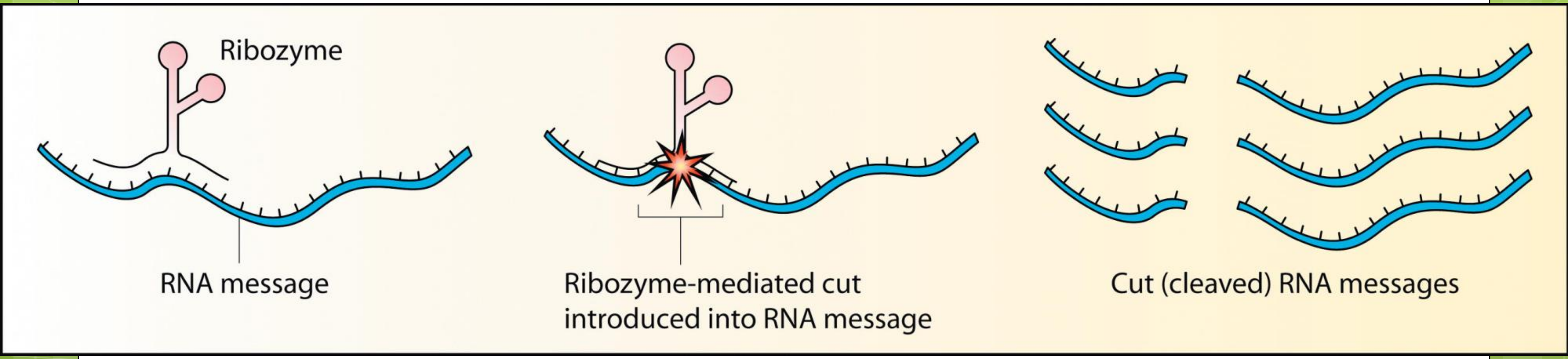



: Plasmid
: Ribosome
1
2
3
4
5
6

The "**RNA World**"

A Hypothetical pre-DNA state of life.

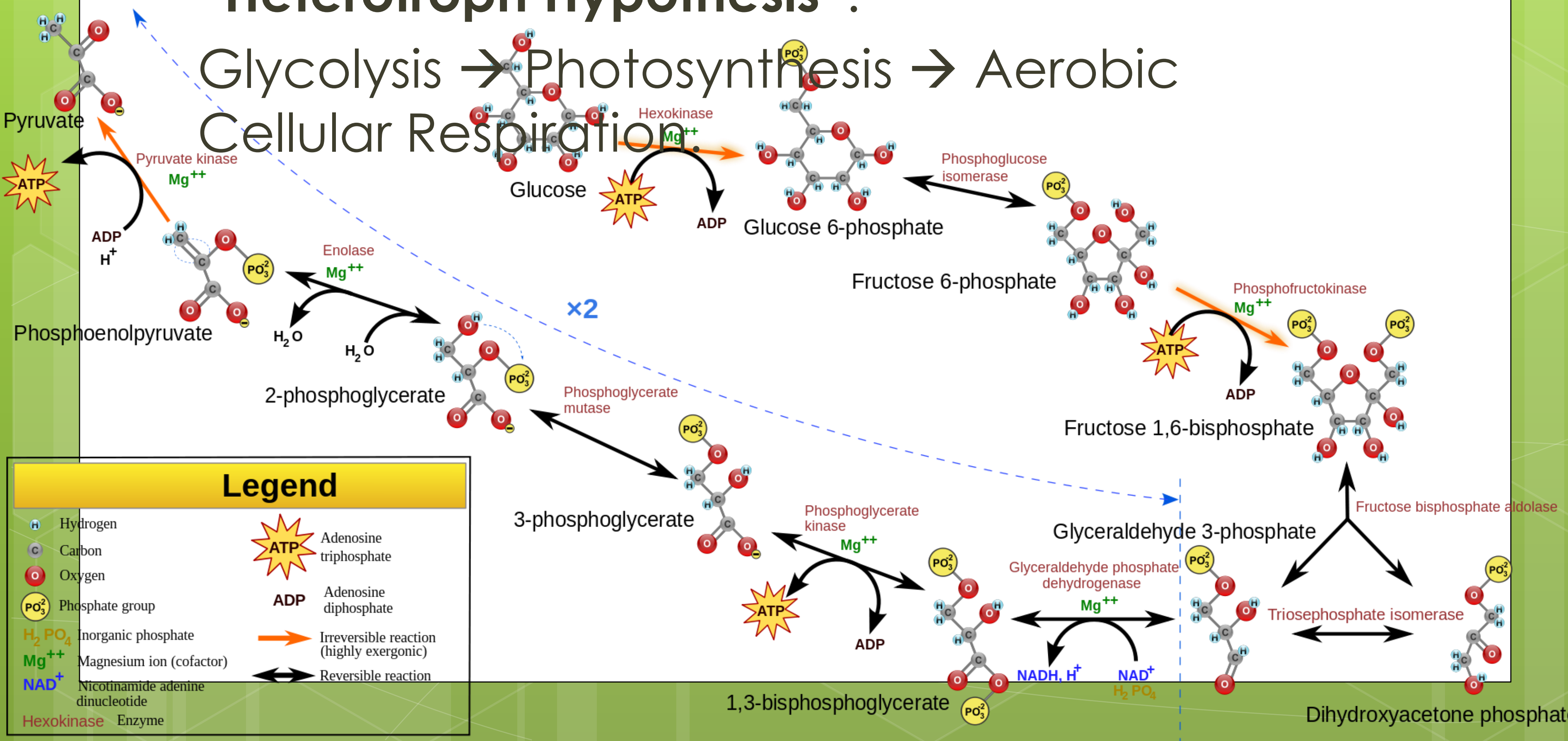
Based on RNA's dual ability to store information AND catalyze reactions.



Evolution of Metabolism

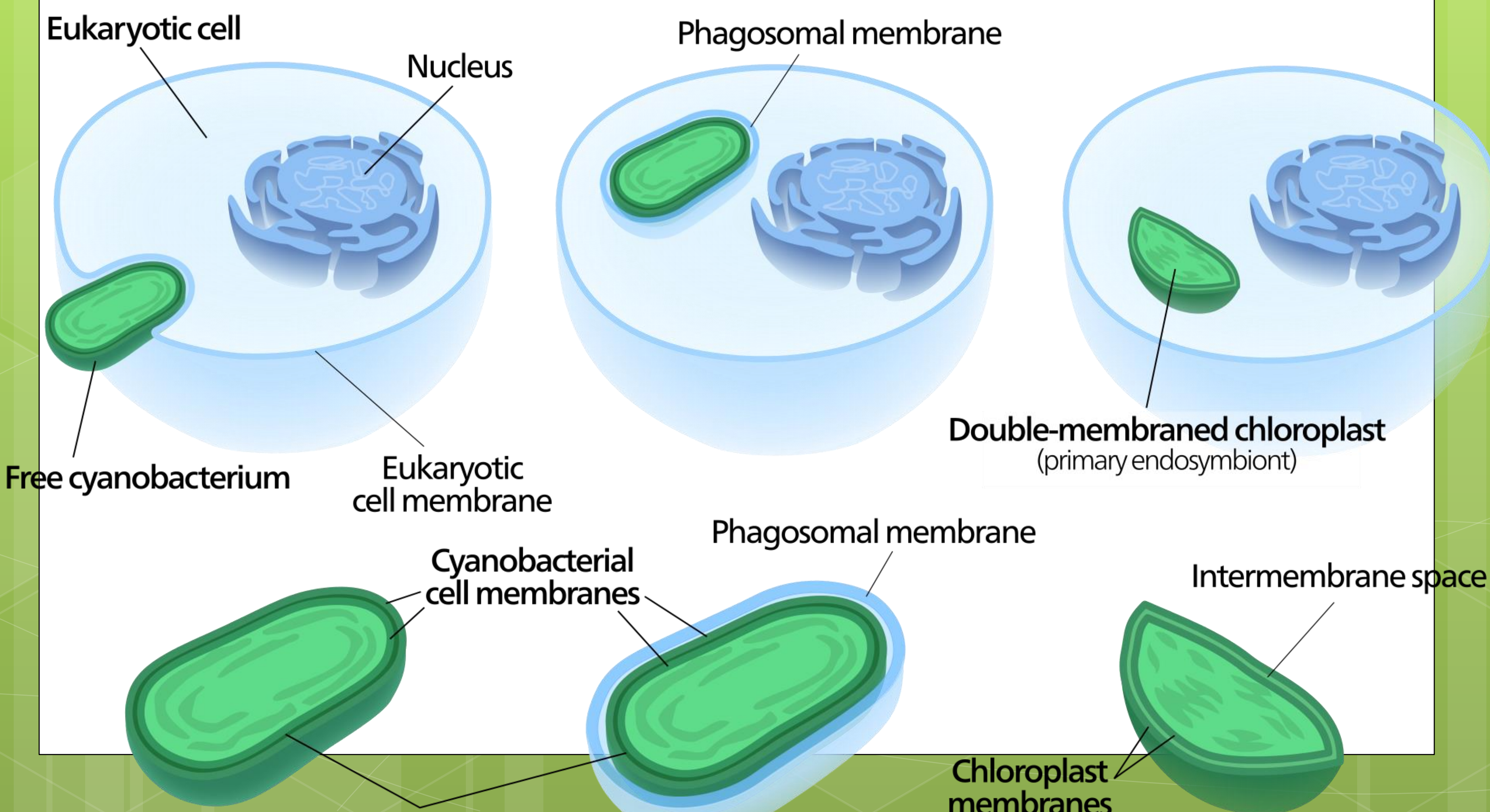
"**Heterotroph Hypothesis**":

Glycolysis → Photosynthesis → Aerobic Cellular Respiration



Endosymbiosis

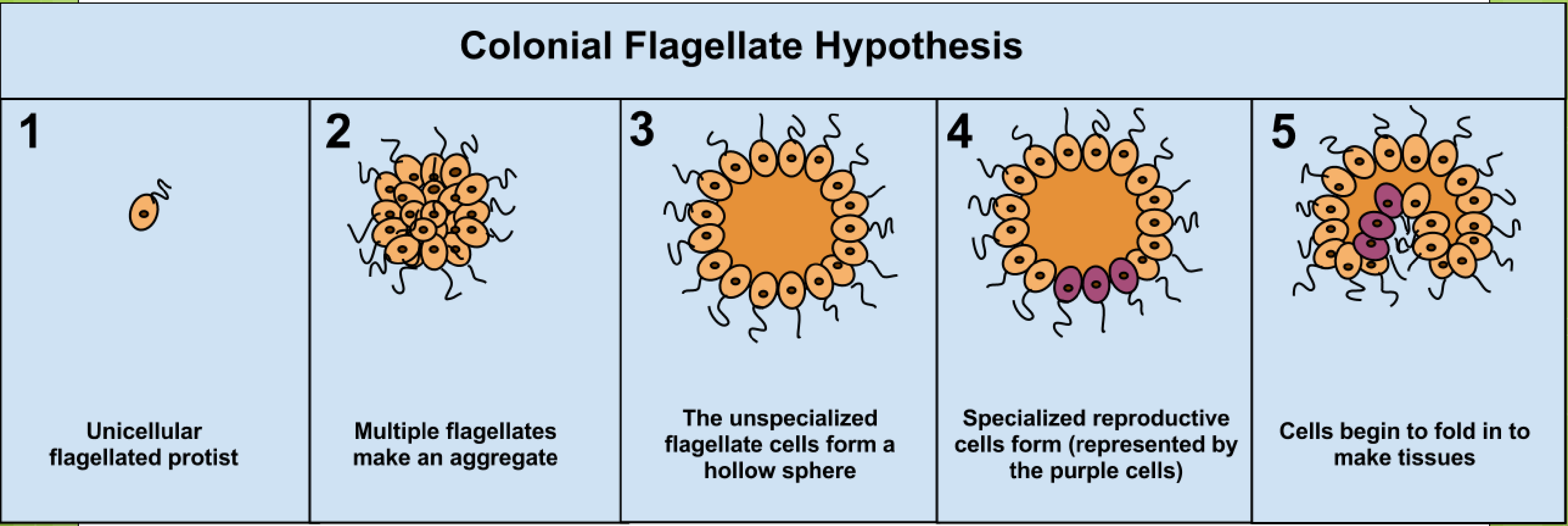
Prokaryote → Eukaryote



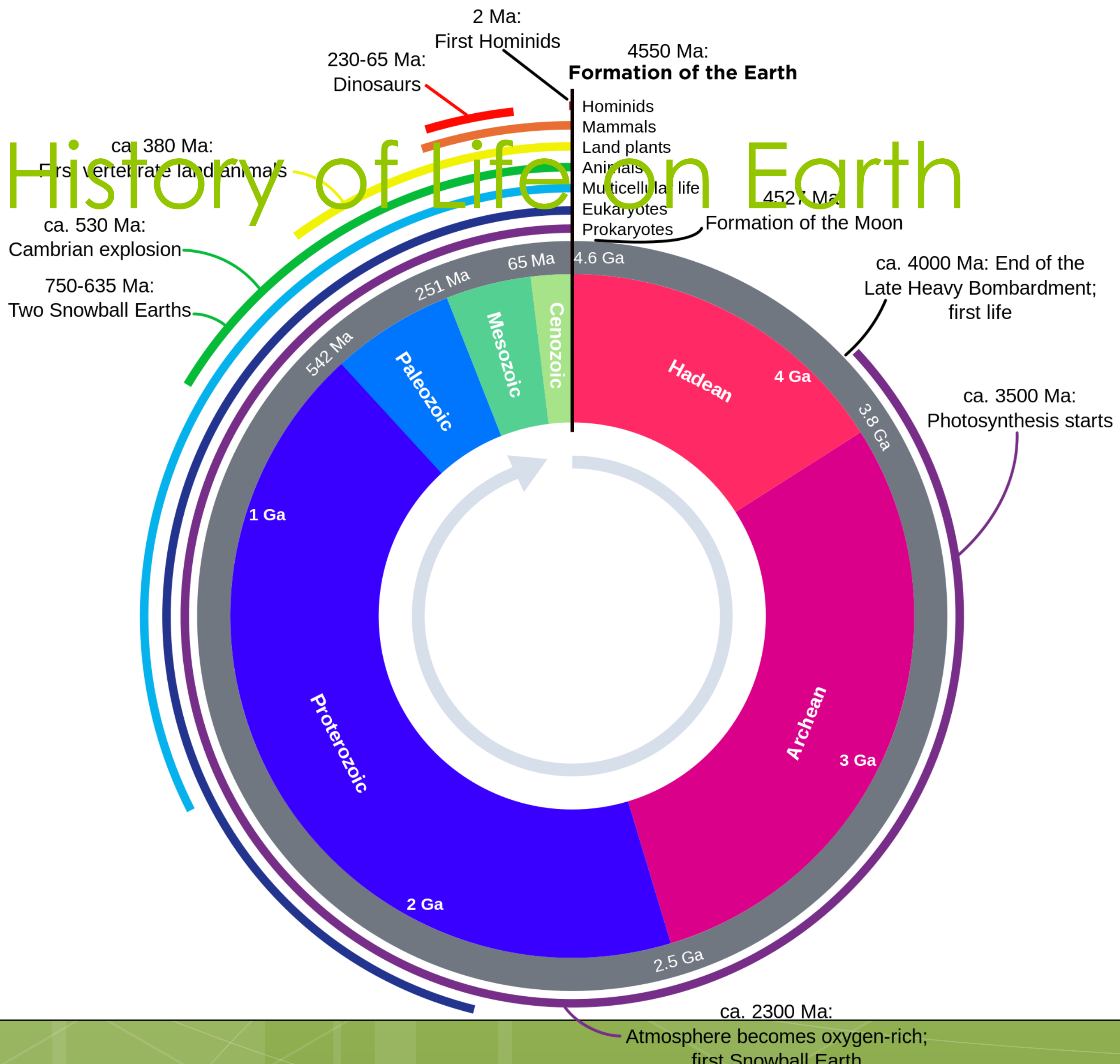
Multicellularity

Multicellularity opens previously inaccessible niches.

Many organisms have unicellular and multicellular stages of their life cycles.

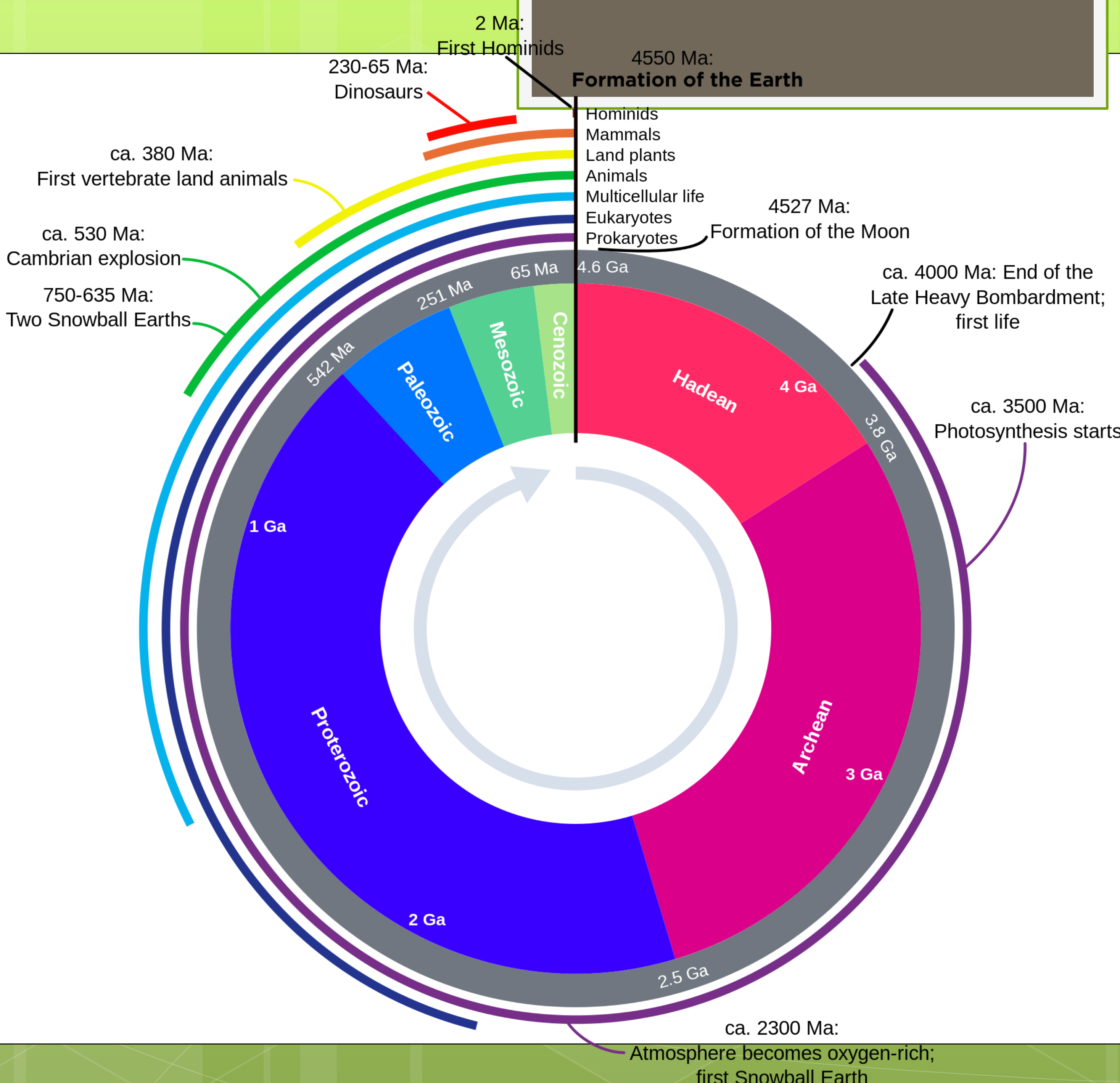


History of Life on Earth



1. Evidence for the Origin of Life

1.11: Scientific evidence from many different disciplines supports models of the origin of life.

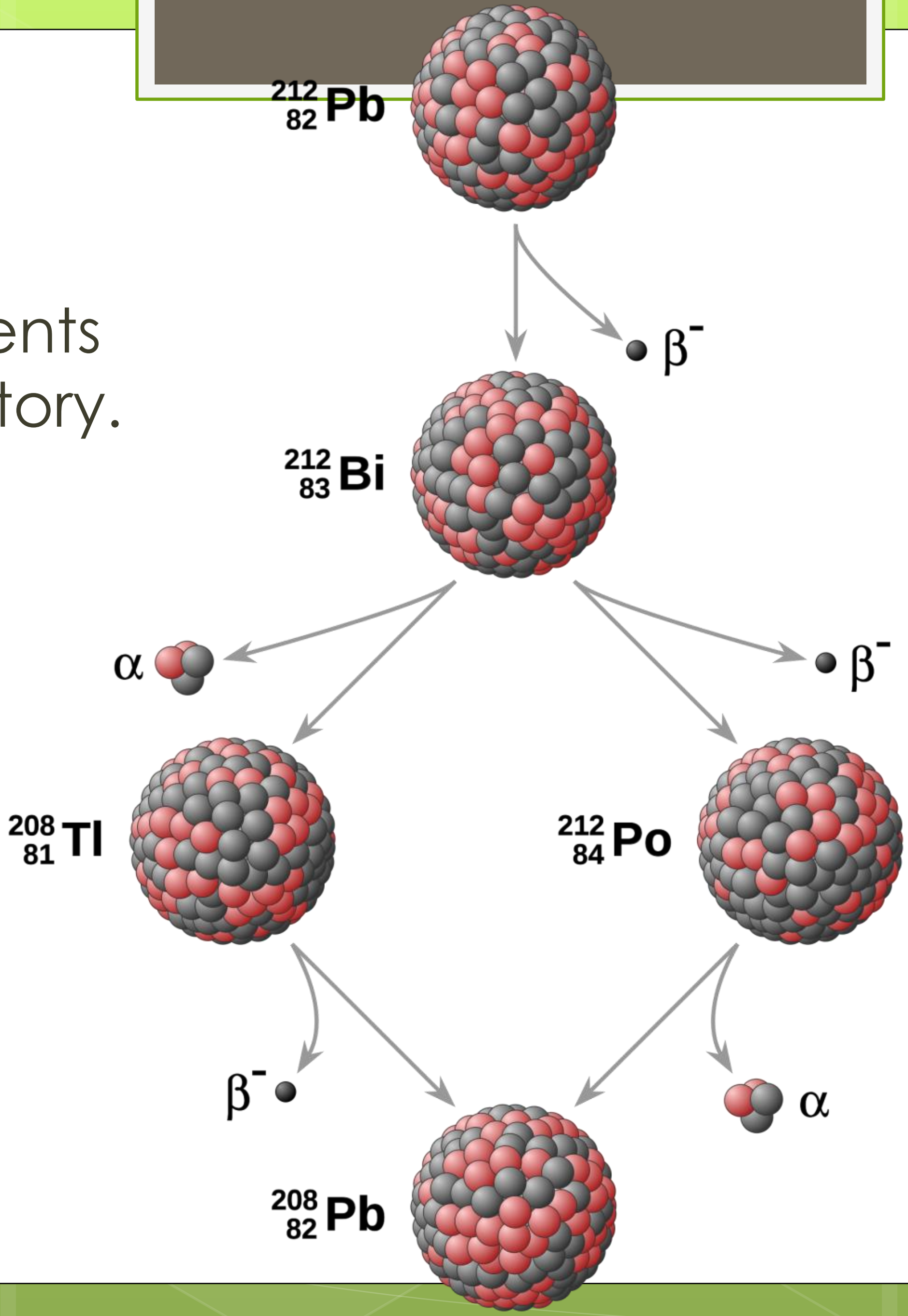


2 Ma:
First Hominids
230-65 Ma:
Dinosaurs
4550 Ma:
Formation of the Earth
Hominids
Mammals
Land plants
Animals
Multicellular life
Eukaryotes
Prokaryotes
ca. 380 Ma:
First vertebrate land animals
ca. 530 Ma:
Cambrian explosion
750-635 Ma:
Two Snowball Earths
4527 Ma:
Formation of the Moon
ca. 4000 Ma: End of the
Late Heavy Bombardment;
first life
ca. 3500 Ma:
Photosynthesis starts
ca. 2300 Ma:
Atmosphere becomes oxygen-rich;
first Snowball Earth
4.6 Ga
65 Ma
251 Ma
542 Ma
Cenozoic
Mesozoic
Paleozoic
Hadean
4 Ga
3.8 Ga
1 Ga
Proterozoic
Archean
3 Ga
2 Ga
2.5 Ga

Geology

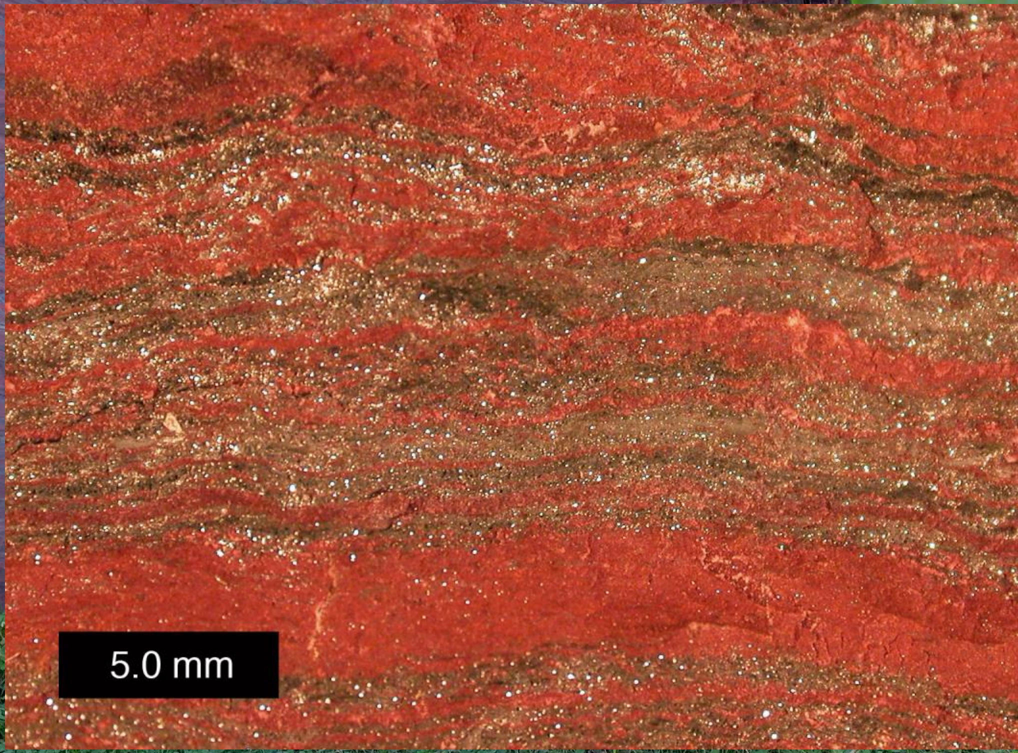
Radioisotope Dating:

Allows estimates of events during evolutionary history.



~65 – 70 mya

Ex. Banded Iron Formations

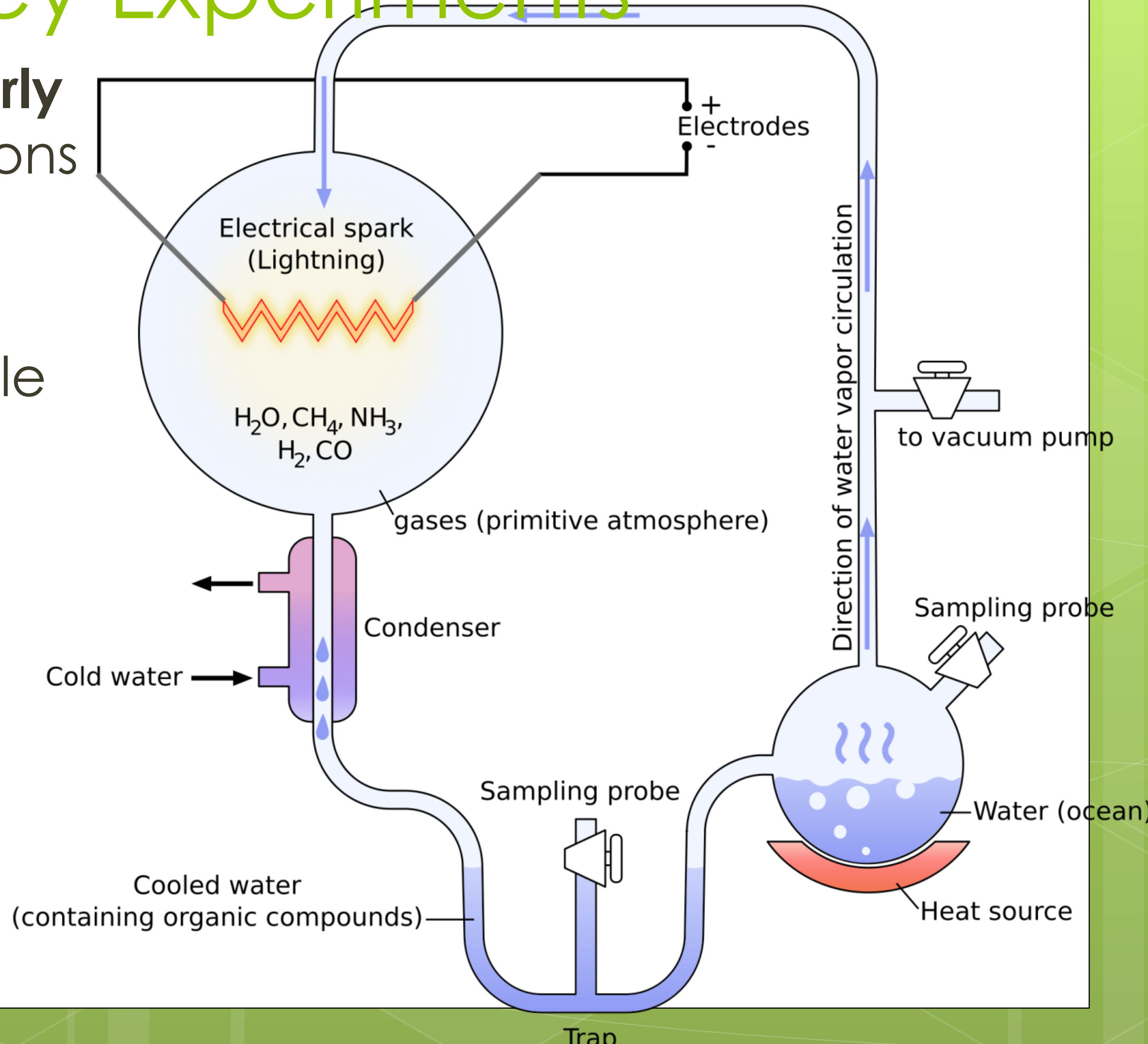


Ex. Fossil Fuels

Miller-Urey Experiments

Simulated **"Early Earth"** conditions (no O_2).

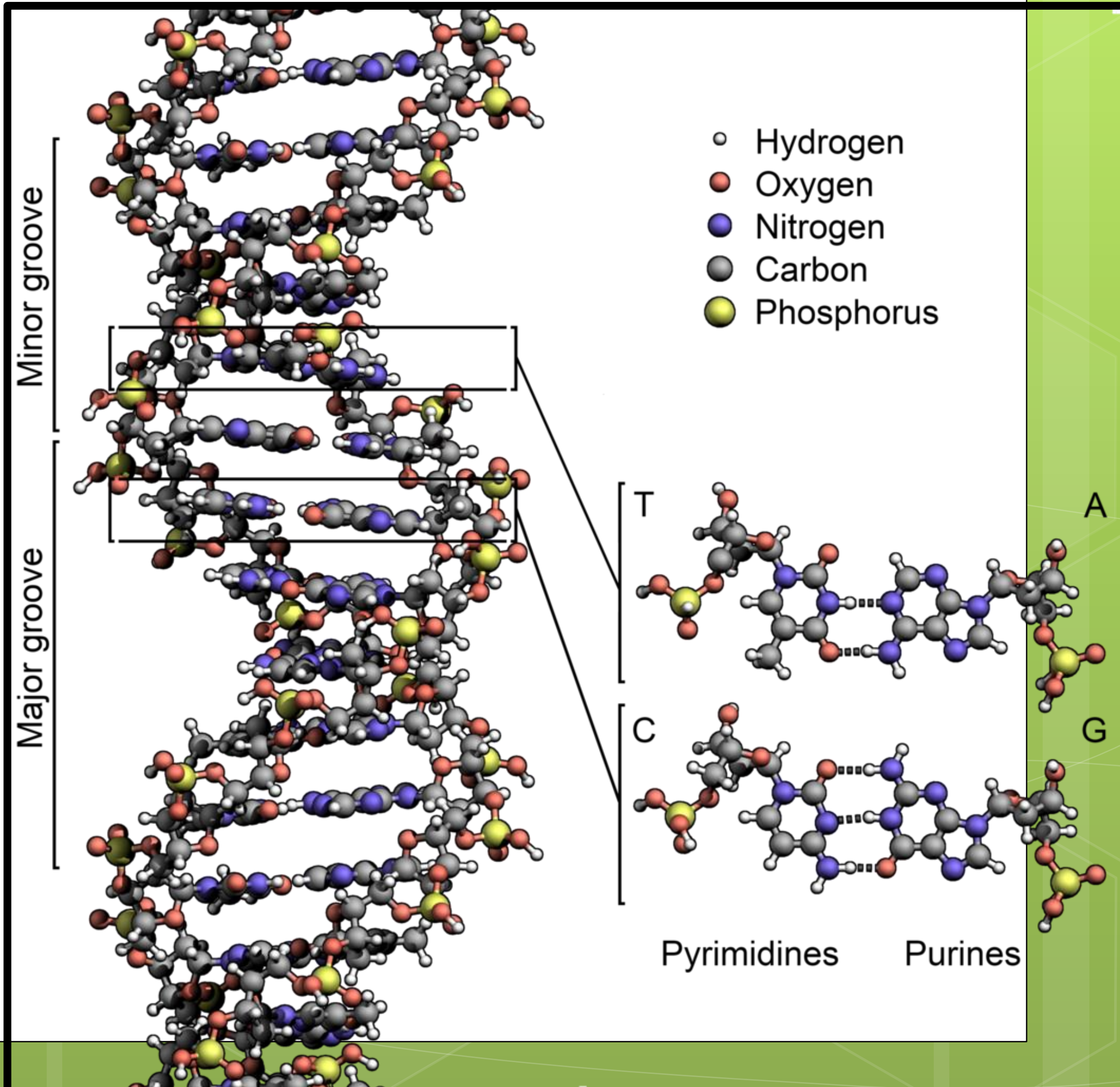
Created Simple Biological Molecules



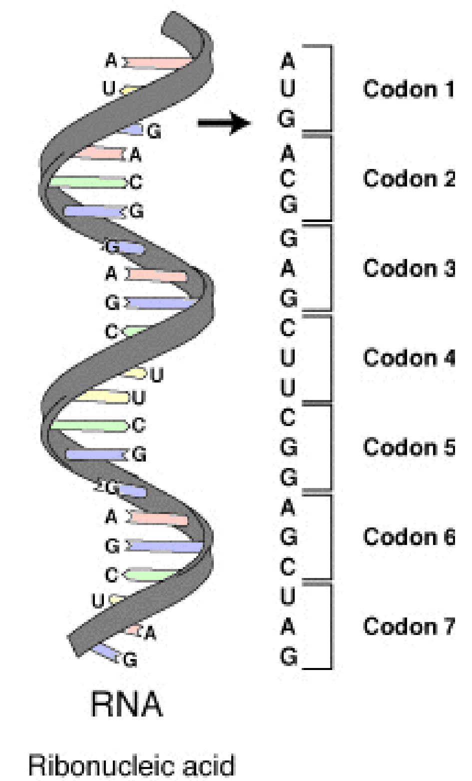
Commonalities among all organisms suggests common ancestry.

It is the simplest explanation for the evidence.

DNA Stores Information in all cells on Earth.



The Genetic Code is universal in all cells

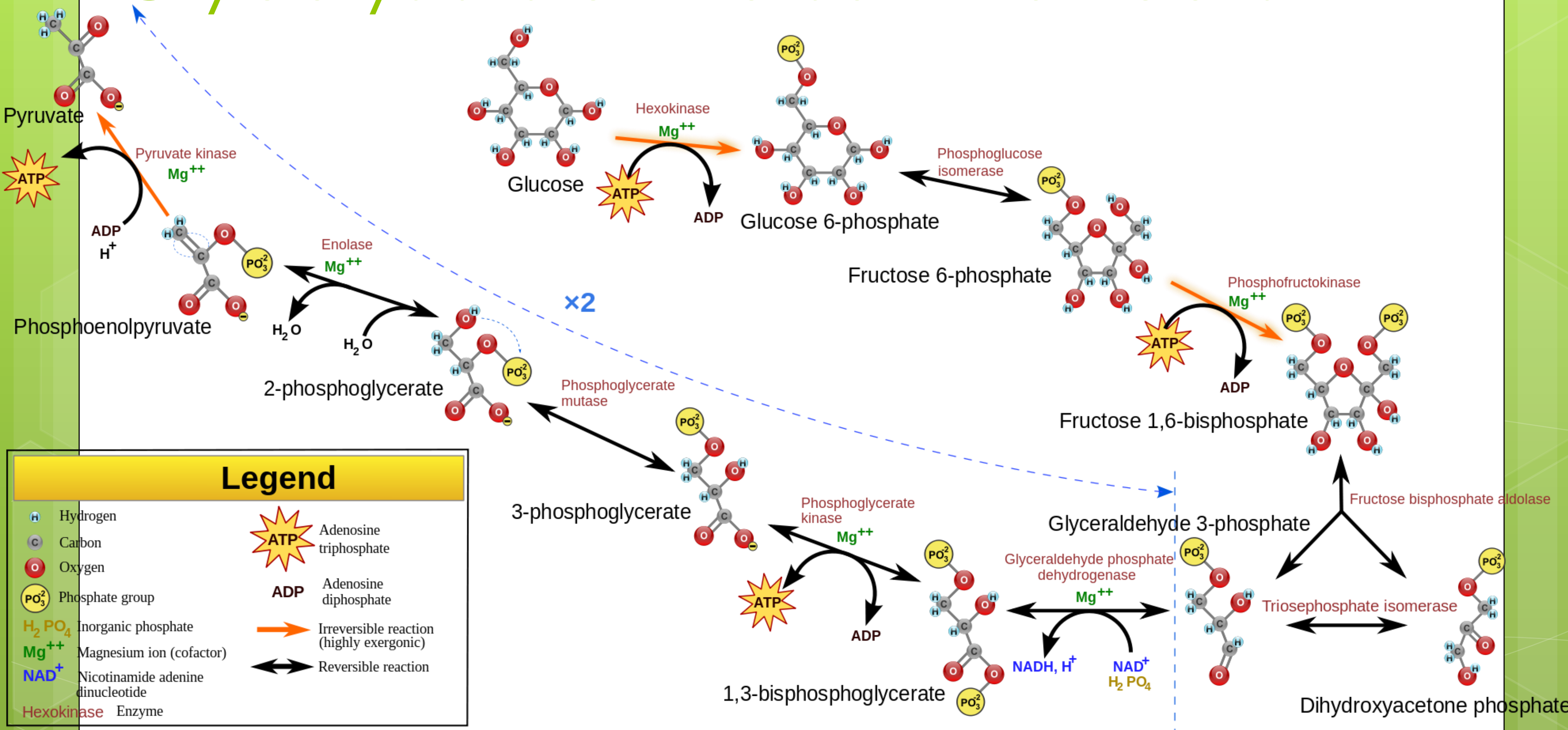


1st base

2nd base	U		C		A		G		3rd bsae
U	UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine	U
	UUC	Phenylalanine	UCC	Serine	UAC	Tyrosine	UGC	Cysteine	C
	UUA	Leucine	UCA	Serine	UAA	Stop	UGA	Stop	A
	UUG	Leucine	UCG	Serine	UAG	Stop	UGG	Tryptophan	G
C	CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine	U
	CUC	Leucine	CCC	Proline	CAC	Histidine	CGC	Arginine	C
	CUA	Leucine	CCA	Proline	CAA	Glutamine	CGA	Arginine	A
	CUG	Leucine	CCG	Proline	CAG	Glutamine	CGG	Arginine	G
A	AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine	U
	AUC	Isoleucine	ACC	Threonine	AAC	Asparagine	AGC	Serine	C
	AUA	Isoleucine	ACA	Threonine	AAA	Lysine	AGA	Arginine	A
	AUG	Methionine (Start)	ACG	Threonine	AAG	Lysine	AGG	Arginine	G
G	GUU	Valine	GCU	Alanine	GAU	Aspartic Acid	GGU	Glycine	U
	GUC	Valine	GCC	Alanine	GAC	Aspartic Acid	GGC	Glycine	C
	GUA	Valine	GCA	Alanine	GAA	Glutamic Acid	GGA	Glycine	A
	GUG	Valine	GCG	Alanine	GAG	Glutamic Acid	GGG	Glycine	G

Nonpolar, aliphatic   Polar, uncharged   Aromatic   Positively charged   Negatively charged

Glycolysis is universal in all cells

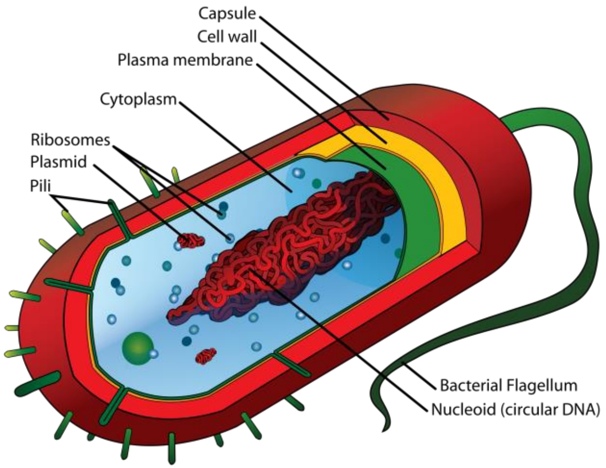


All life is organized into cells

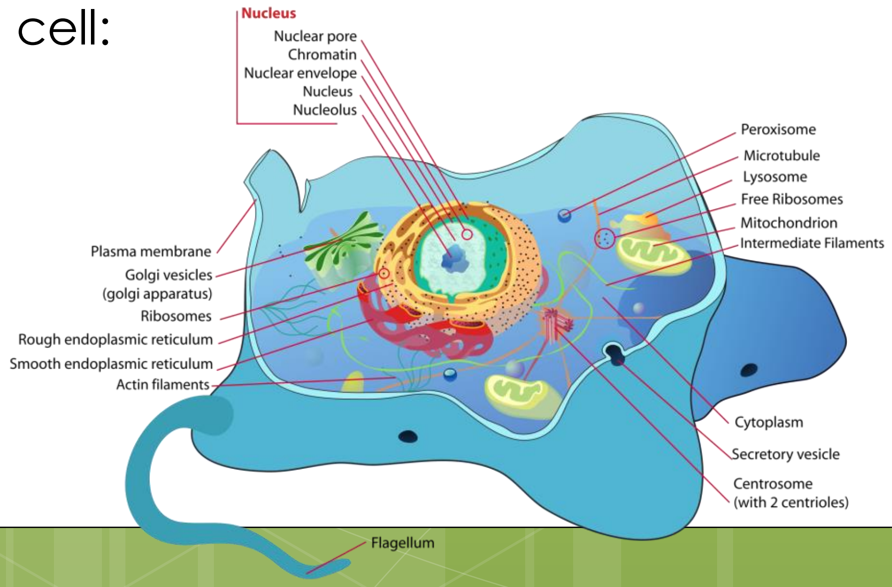
These cells contain fundamental structural similarities

Note: Not to scale.

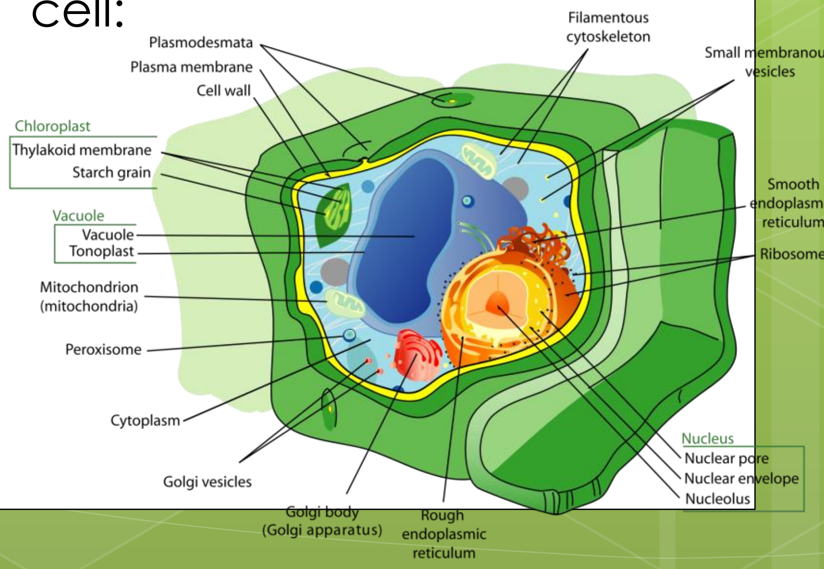
Prokaryotic Cell:



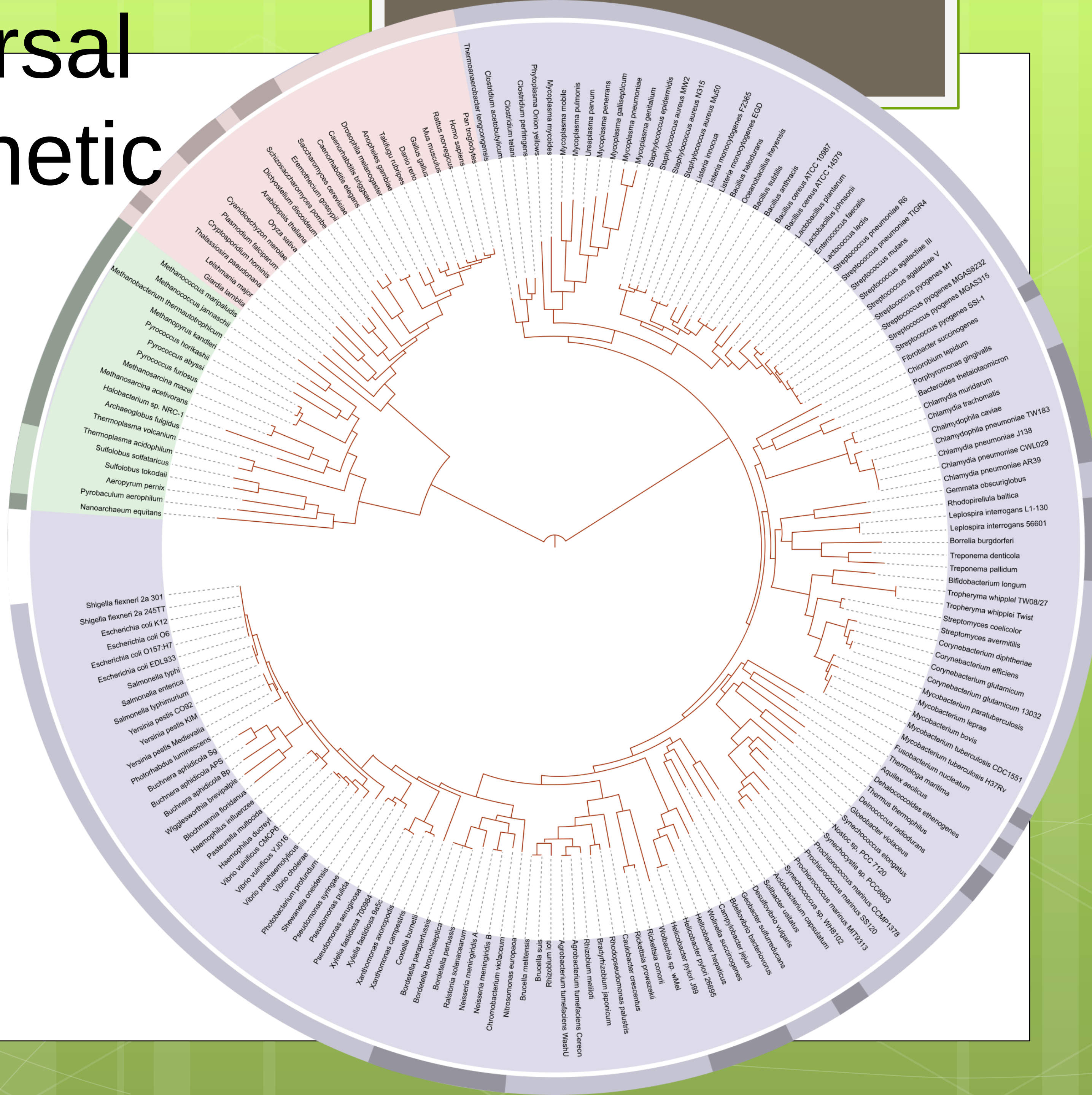
"Animal-like" eukaryotic cell:



"Plant-like" eukaryotic cell:



A Universal Phylogenetic Tree



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Exceptions

slide 23: Image from Grant & Grant, 2002.

Slide 96: Image and Diagram from M. Nachman