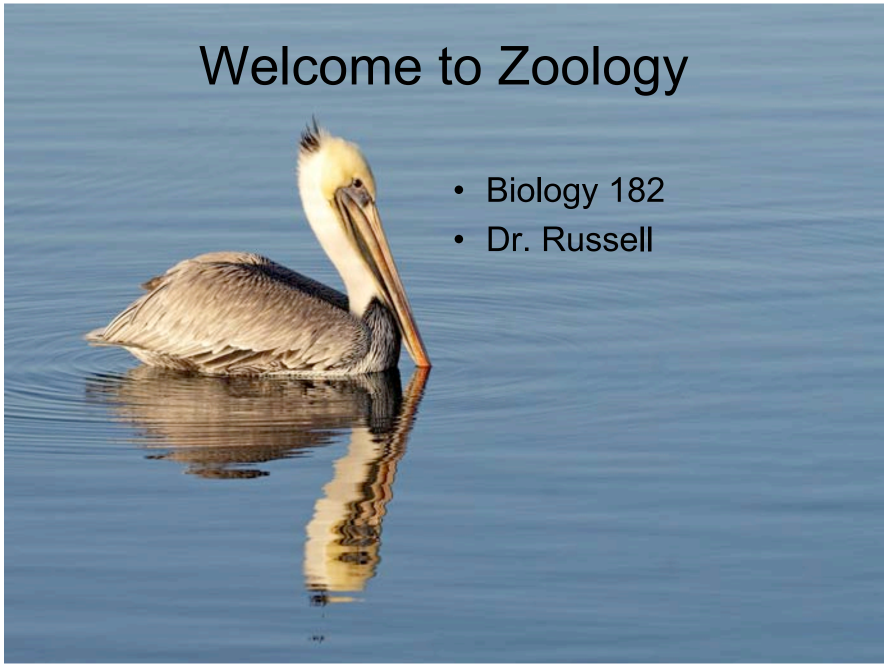


My Background

Who is this class for?

- Anyone interested in the study of animals
- Biology and other natural science majors
  - Biology 181 is no longer a prerequisite
  - Check with your desired transfer universities for course requirements on www.assist.org

Today

- Review the course and policies
- Begin a study of the diversity of organisms

What is this course all about?

- The anatomical and physiological systems of most common taxa of animals, including
  - Relationships between major groups of animals
  - Reproduction and Development
  - Nervous and Sensory systems
  - Skeletal system and Locomotion
  - Osmoregulation
  - Adaptation and Homeostasis
  - Circulation and Respiration
  - Feeding and Digestion

Zoology Student "To Do" List

- Come to class prepared
- Participate during class and ask questions
- Spend time outside of class on this class
  - Take your time to make notes and write down questions while you read the textbook
  - Review notes you took in class
  - Try to apply what you're learning to the world around you
  - Use the Internet links provided on my website
  - Come to my office hours
- Know your classmates

How will I earn my points?

- Four lecture exams
  - In class, a mix of multiple choice, true or false, matching, and short answer.
  - The final exam is comprehensive
- Eight journal entries
  - You will be given a prompt, and will write a short essay on a question, a reading, etc.
  - Further information will be provided later
- Other, occasional, skill-building assignments

Other policies

- Attendance
  - Can miss up to 3 days of class before possibly being dropped
  - Do NOT depend on me or our course assistant to drop you!
- Academic honesty
- Late work
- No extra credit will be offered

Biological diversity and classification

My primary course focus is:

Functional biology of multicellular organisms

(how organisms are put together and how their structure and physiology let them 'work' in their environments)

In order to deal with these questions, we need to deal with **biological diversity**

Two very important levels of diversity in biology:

1. **There are _many_ different species of organisms--interspecific variation**
2. **Within species, *each individual is different from every other individual* (this intraspecific variation is unique about biology, compared to chemistry or physics)**

Biological diversity and classification

What do we know about diversity (and what don't we know)?

We know there are a lot of species--about 2 million have been described (collected, preserved, analyzed, and formally discussed in the scientific literature)

Approximate numbers of **described** species in various groups

Plants ~300,000

Assorted invertebrates (not arthropods)

~100,000

Arthropods

>1,000,000

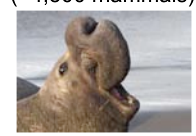
Insects

~900,000 (> 350,000 beetles!)

Vertebrates

~60,000

(~4,500 mammals)



Biological diversity and classification

What do we know about diversity (and what don't we know)?

We know there are a lot of species--about 2 million have been described (collected, preserved, analyzed, and formally discussed in the scientific literature)

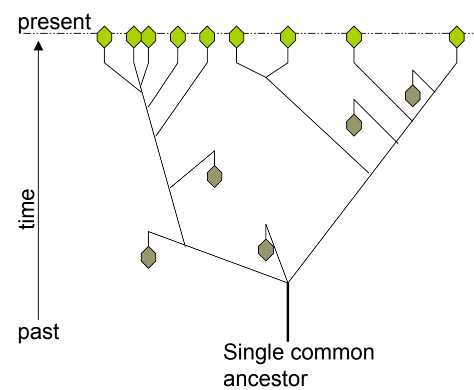
We know there are huge differences in form and function between these species. We also know that there are many fundamental *commonalities* as well (DNA code, sequence similarity, biochemistry, cell structure and function, etc.)

We know that the commonalities are there because of life's **evolutionary history**: *descent with modification*

Therefore, we can *organize our knowledge* with a hierarchical system based on evolutionary relationships. This describes common ancestry, rather like a geneology or family tree.

Biological diversity and classification

Phylogenetic relationships--historical patterns of species formation

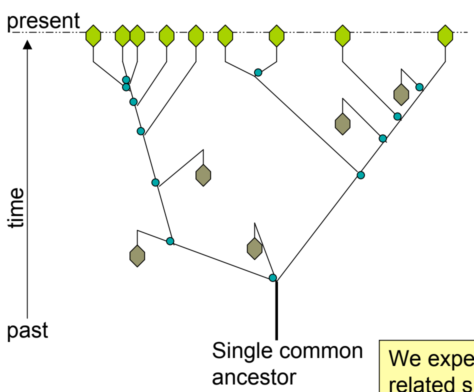


Phylogeny is often described as a "**tree**" as symbolized here:

- the 'trunk' is the most deeply ancestral form
- the 'branches' are more recent ancestors
- the green 'leaves' represent existing species
- the dead 'leaves' represent extinct lineages

Biological diversity and classification

Phylogenetic relationships--historical patterns of species formation



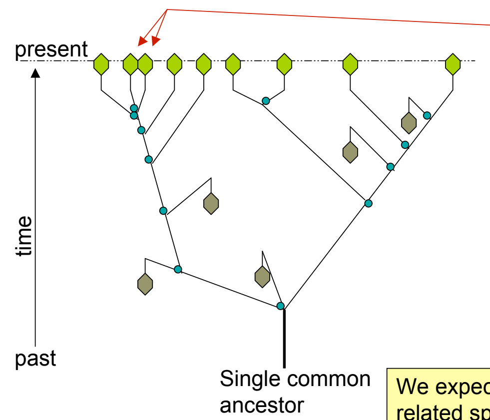
What's important are the branch points (•) which indicate last common ancestors--events that formed new lineages

Lineages separated by few branch points are generally more related by lineages separated by many branch points

We expect more similarity in closely related species than in distantly related species--there has been less time for evolutionary change from ancestral forms

Biological diversity and classification

Phylogenetic relationships--historical patterns of species formation



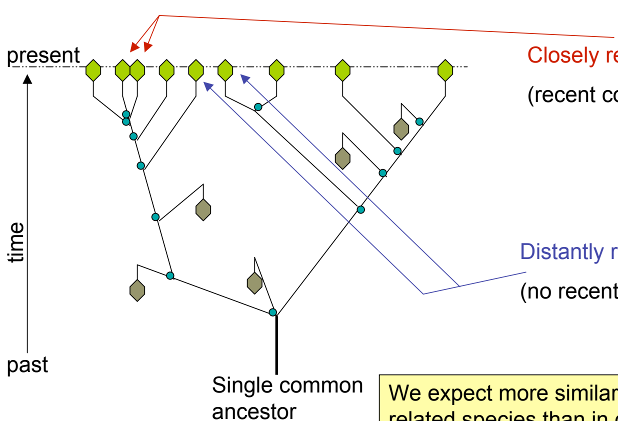
Closely related

(recent common ancestor)

We expect more similarity in closely related species than in distantly related species--there has been less time for evolutionary change from ancestral forms

Biological diversity and classification

Phylogenetic relationships--historical patterns of species formation



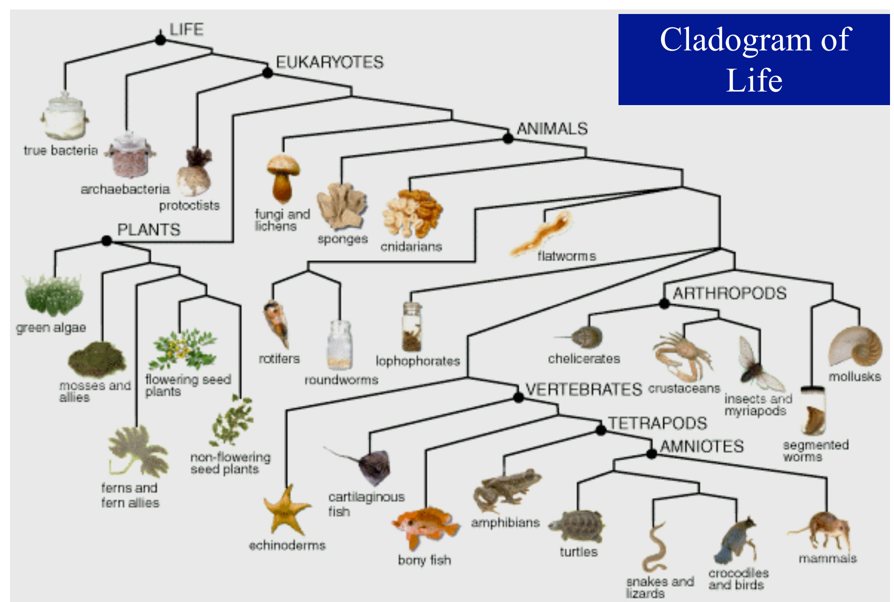
Closely related

(recent common ancestor)

Distantly related

(no recent common ancestor)

We expect more similarity in closely related species than in distantly related species--there has been less time for evolutionary change from ancestral forms

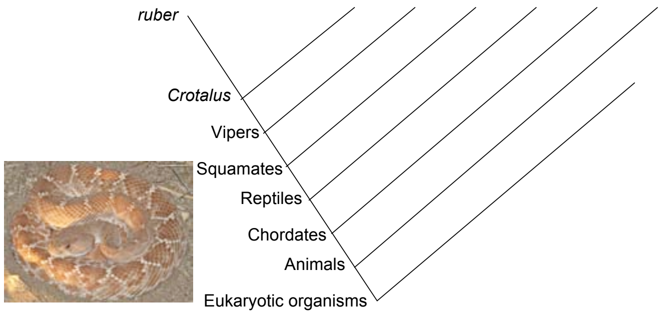


Biological diversity and classification

Phylogenetic relationships--historical patterns of species formation

Many categories (levels); the most traditional and important are:

- Species
- Genus (genera)
- Family
- Order
- Class
- Phylum (phyla)
- Kingdom
- Domain



Species is the most specific and restrictive category; **domain** is the broadest and most inclusive (3 domains; millions of species).

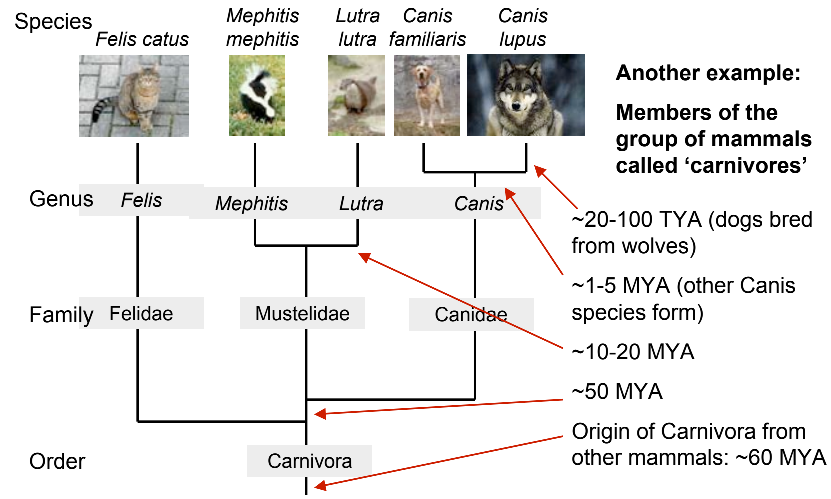
A species scientific name is **binomial**: the combination of genus and species names. For example, red diamond rattlesnakes (*Crotalus ruber* above), or fruit flies, or people:
- genus *Drosophila*, species *melanogaster*: species name *Drosophila melanogaster*
- genus *Homo*, species *sapiens*, species name *Homo sapiens*

Biological diversity and classification

Phylogenetic relationships--historical patterns of species formation

Another example:

Members of the group of mammals called 'carnivores'



Biological diversity and classification

Hierarchical classification based on evolutionary relationships lets us arrange our knowledge from the most specific to the most general way *that allows accurate predictions about unstudied organisms*. **This is crucial for 3 reasons:**

1. **The vast majority of species have not been discovered and described.** We know of about 2 million species, but the best estimates of the *total* number of *living* species are 10-30 million. So we only discovered 7-20% of them--and many will become extinct before they can be described.

   Most undiscovered species are probably insects and other small organisms.

   And of course, there are millions of *extinct* species as well. The number of extinct species is much larger--perhaps by 100x--than the number of species currently existing.

Biological diversity and classification

Hierarchical classification based on evolutionary relationships lets us arrange our knowledge from the most specific to the most general way *that allows accurate predictions about unstudied organisms*. **This is crucial for 3 reasons:**

2. **Only a tiny fraction of *described* species have been studied in any detail**: Most have simply been described in terms of basic overall morphology (what they look like).
   - A few have been examined in more detail: physiology, ecology, development, reproduction, behavior, etc.
   - A *very* small number of **"model" organisms** are the best studied of all, and their biology is understood in considerable detail: *Eschericia coli* (bacterium), *Chaenorhabditis elegans* (nematode worm), *Drosophila melanogaster* (fruit fly), *Brachydanio rerio* (zebrafish), *Mus musculus* (*M. domesticus*) house mouse

Biological diversity and classification

Hierarchical classification based on evolutionary relationships lets us arrange our knowledge from the most specific to the most general way *that allows accurate predictions about unstudied organisms*. **This is crucial for 3 reasons:**

3. **We will never be able to know everything about every living organism**--there is simply too much to know, and organisms are constantly changing (evolving) and going extinct.

Therefore, our understanding will always be incomplete

However…

Biological diversity and classification

Because we use a **hierarchical system based on evolution**, we don't require *complete* knowledge to provide very useful insights into *generalities*.

An example of generalization: we're confident that all organisms* use DNA as genetic material and that the DNA coding scheme is the same for all. This has been *tested* on only a tiny fraction of species, but because our classification scheme is a general one, we can be very sure this generalization is universally true.

**Not counting viruses--some of which use RNA instead of DNA*

Biological diversity and classification

Because we use a **hierarchical system based on evolution**, we don't require *complete* knowledge to provide very useful insights into *generalities*.

More examples of the value of this ability to generalize:

- We know a great deal about many aspects of the biology of the fruit fly *Drosophila melanogaster*. Therefore we **also** know a lot about other species of *Drosophila*, a bit less about other kinds of flies, and something about insects in general.
- If we know a great deal about disease pathology, causality, and treatment in mice, rats, or monkeys, we *also* know a lot about the causes, pathology and treatment of similar diseases in **people**.

Biological diversity and classification

What information do we use to deduce phylogenies?

Many different lines of evidence are considered:

- Early workers used comparative anatomy, physiology, embryology (developmental patterns), and fossil evidence
- More recently, comparative biochemistry, behavior, etc.
- The latest approaches use analysis of DNA sequences

A crucial point: Although we are constantly revising the details of the 'tree' with new information, it is important to know that **the different kinds of information used for phylogeny *reconstruction*****--*****even extremely different ones such as fossils, embryology, and*** ***DNA*****--*usually* give more or less the same answers**. ⇒ This is evidence that our understanding of evolutionary history is reasonably accurate.

Homologous Structures

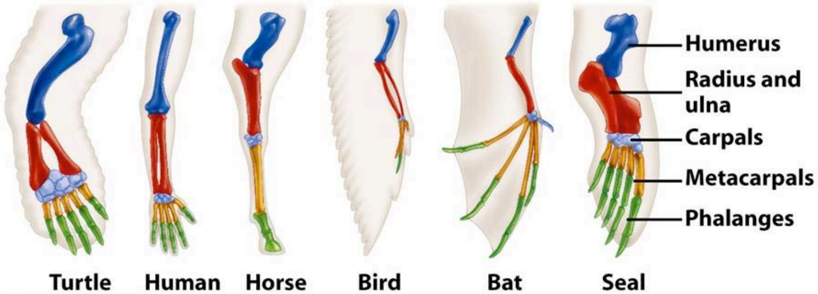
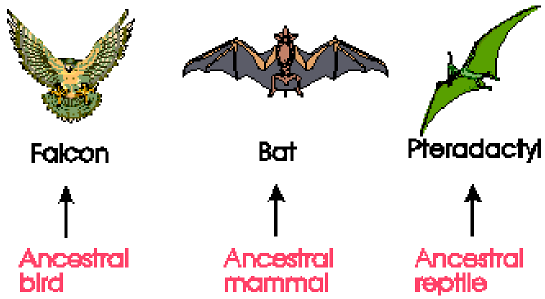
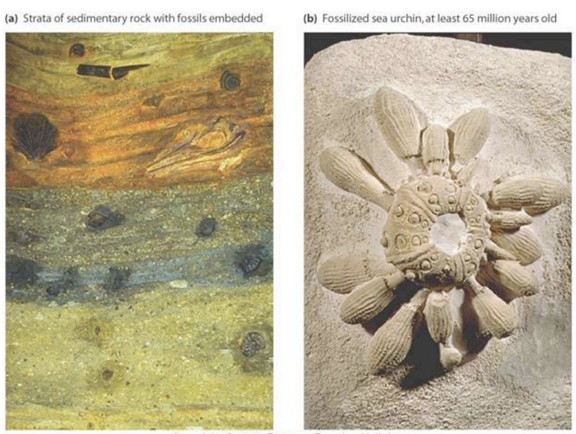


Figure 23-6 Biological Science, 2/e

Convergent Evolution



Fossils



Developmental Homology

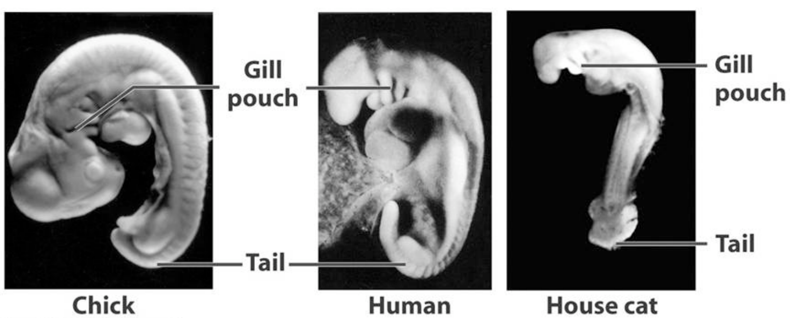
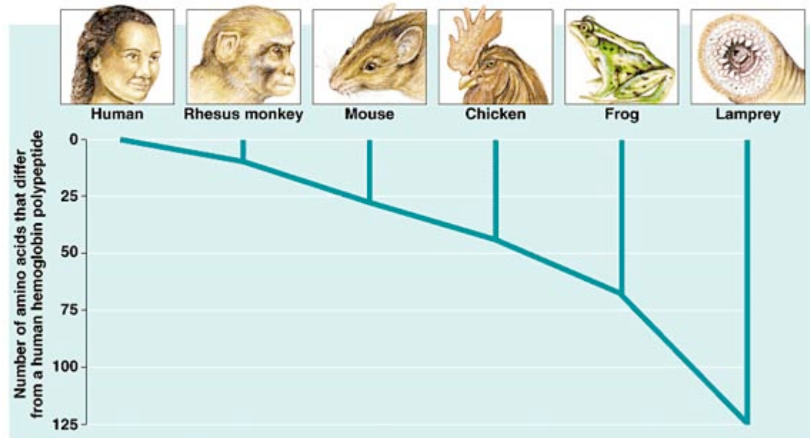


Figure 23-7 Biological Science, 2/e

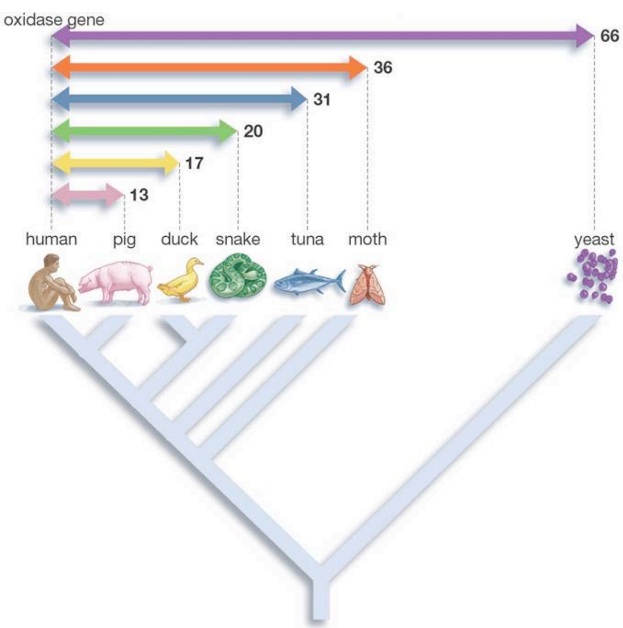
Molecular Evidence

- Mitochondria DNA (mtDNA)
  - Cytochrome C
- RNA
- Proteins
  - Hemoglobin
  - Myoglobin
- DNA

Amino Acid Sequence Comparison for the Protein Hemoglobin

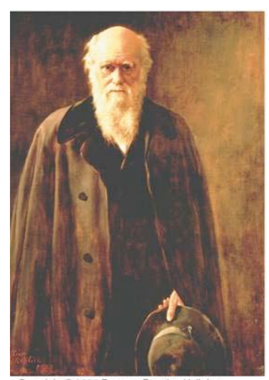


Cytochrome C (number of DNA nucleotide base difference)

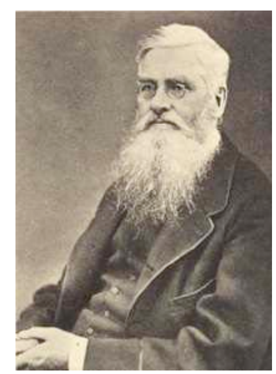


The Theory of Evolution by Natural Selection

Charles Darwin and Alfred Russell Wallace (1858) state the Theory of Evolution:



- All species past and present are related by descent from a common ancestor
- Species change through time ("descent with modification").



Past Contributors and Disciplines

- Ideas of evolution can be traced back to the time of early Greek philosophers

- Thomas Malthus: Political Economist
  - MAIN IDEAS: overpopulation & loss of resources
- Charles Lyell: “Father of Geology”
  - MAIN IDEAS: Earth is old & dynamic
- Georges Cuvier: Paleontologist
  - MAIN IDEAS: comparative organismal biology & fossils in rocks of extinct species
- Jean-Baptiste de Lamarck: Zoologist
  - MAIN IDEAS: organisms change individually (incorrect), and pass on their traits to their offspring (correct)

The mechanisms of evolutionary change

Our classification scheme is based on **lineage relationships**: a ‘pedigree’ of **descent with modification**. ‘Descent with modification’ = genetic change across generations = the definition of evolution.

The fact that organisms have evolved--and transfer genetic information to subsequent generation--means that their <u>history</u> is a crucial factor in their <u>current</u> biology.

• **in organisms, the past very strongly influences the present, and the present will very strongly influence the future.**

• **again, this aspect of biology is very unlike many other sciences** (example: the past history of a molecule, or its component atoms, has no influence on its current chemical characteristics).

The mechanisms of evolutionary change

Our classification scheme is based on **lineage relationships**: a ‘pedigree’ of **descent with modification**. ‘Descent with modification’ = genetic change across generations = the definition of evolution.

How and why does evolution occur? What <u>causes</u> a species’ genetic information to change over generations?

Four primary factors:

• **mutation**: random genetic changes

• **gene flow**: immigration of new genes (alleles) from other populations

• random ‘**genetic drift**’ (especially in small populations)

• natural selection <-- probably he most important source of change, because it’s <u>not random</u>.

How does selection work?

The mechanisms of evolutionary change

How does selection work?

The details are hugely complex (due to interactions between genes, environmental effects, interactions between genes and environment, etc.).

BASIC PRINCIPLE IS EXTREMELY SIMPLE:

Can be summarized in three **observations** and three **inferences**.

Natural selection: three observations and three inferences

OBSERVATION #1: **Variation exists** in almost all biological traits in all species. This is obvious even from casual observation.

OBSERVATION #2: Some of this variation is **heritable**: encoded in the DNA. Again, this is easy to verify.

- variation in **traits** (morphology, physiology, etc.) is partially due to variation in **genes**.
- variation in genes (genetic variations) comes from **mutation** and **sex**.

OBSERVATION #3: All organisms have a *potential* reproductive rate that is **much higher than the *actual* reproductive rate**.

- Darwin calculated that one pair of elephants would have 19 million offspring in 750 years if all offspring survived and reproduced.
- Mice: a single pair could cover the Earth with their descendants in about 5 years (about 33 millions descendants in two years!!)

Natural selection: three observations and three inferences

OBSERVATION #1: **Variation exists**

OBSERVATION #2: Some of this variation is **heritable**

OBSERVATION #3: Organisms *can* reproduce faster than they *do* reproduce

INFERENCE #1: Not all young that are born survive to reproduce; therefore there must be **competition**.

- *much* direct evidence showing high mortality and competition

INFERENCE #2: Because of variance in **phenotype**, some individuals are better able to **compete** (survive and reproduce).

- plenty of evidence showing differential survival and reproduction.

INFERENCE #3: Successful individuals will contribute disproportionately to the genes in the next generation. Because some of the variation in **phenotype** is heritable, the next generation will have a higher frequency of advantageous genes.

Natural selection: three observations and three inferences

OBSERVATION #1: **Variation exists**

OBSERVATION #2: Some of this variation is **heritable**

OBSERVATION #3: Organisms *can* reproduce faster than they *do*

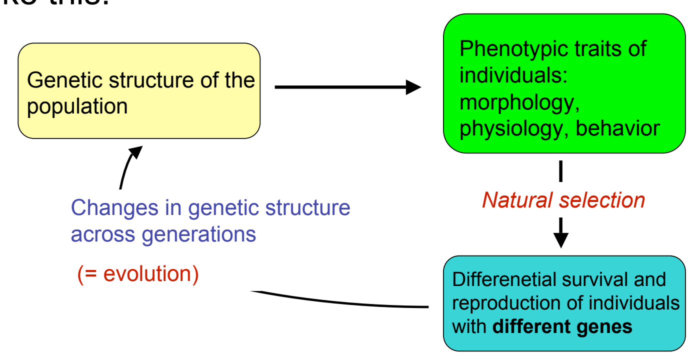
This is a change in the **genetic structure of the population**, *which is the definition of evolution*.

There is lots of direct evidence of this happening all the time.

n.

INFERENCE #3: Successful individuals will contribute disproportionately to the genes in the next generation. Because some of the variation in **phenotype** is heritable, the next generation will have a higher frequency of advantageous genes.

Natural selection: a constant and repeating process that proceeds in an endless loop across generations, like this:



Natural selection can lead to either evolution (change over time) or stability (no change over time), depending on circumstances.

- **directional** or **disruptive** selection (leading to change)
- **stabilizing** selection (leading to stasis)

Things to keep in mind about evolution:

- It is both **random** (mutation, gamete matching, environmental events, etc.) and **non-random** (selection).
- IT IS NOT GOAL ORIENTED! Organisms don't "decide" to evolve something. Selection responds only to **existing conditions**, and to the organism's history as coded by the information in the genes.
- The "currency" of selection is NOT survival. What matters is REPRODUCTIVE SUCCESS.
- It can be quite fast, and _small_ differences have a big effect over time:

Example: consider a mutation in one individual that gives its carrier a 1% better reproductive success. Even if nothing else chnages, in 100 generations, this mutation will be in 73% of the population, and in 500 generations it will be in 99.3% of the population.

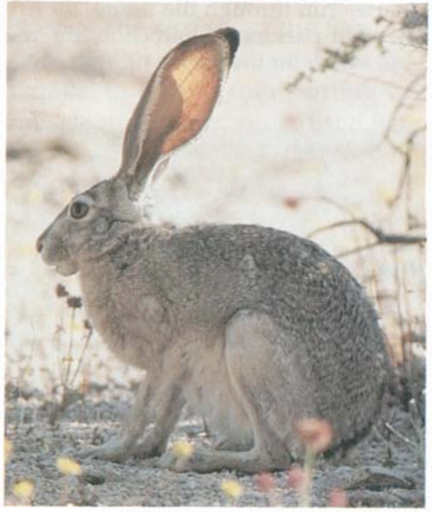
A 5% advantage is in 99.2% of the population in 100 generations.

Natural selection does not grant organisms what they "need".

Evolutionary Adaptation vs. Physiological Adaptation (Acclimation)

Adaptation

Desert Jackrabbit



Arctic Hare

From Purves et al. 1994

Acclimation

- Summer coat
- Winter coat

Kangaroo Rat Adaptations

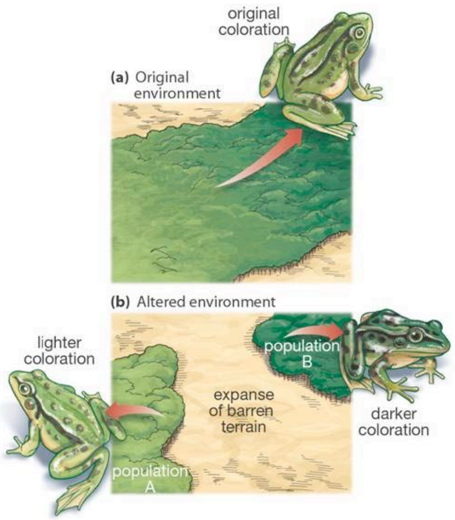
Which of the following is an evolutionary adaptation?

1. Whales depositing more fat as they migrate to colder waters
2. “Warm-blooded” animals shivering as it gets colder
3. Primates having opposable thumbs
4. Mammalian kidneys concentrating urine more when you don’t drink enough water

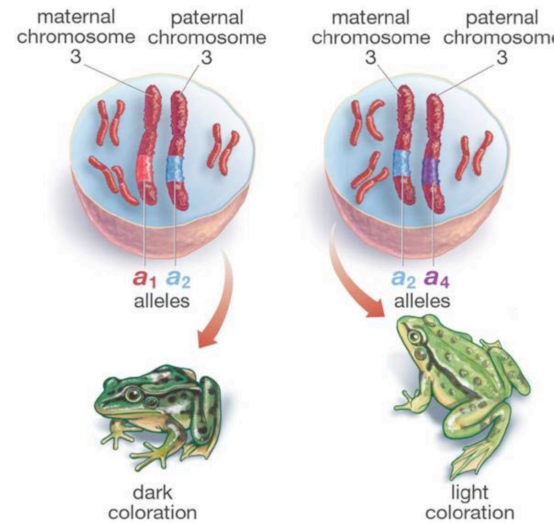
Microevolution

How does it happen?

POPULATIONS



In Your Genes



Must evolution happen, and *<u>when</u>* does it happen?

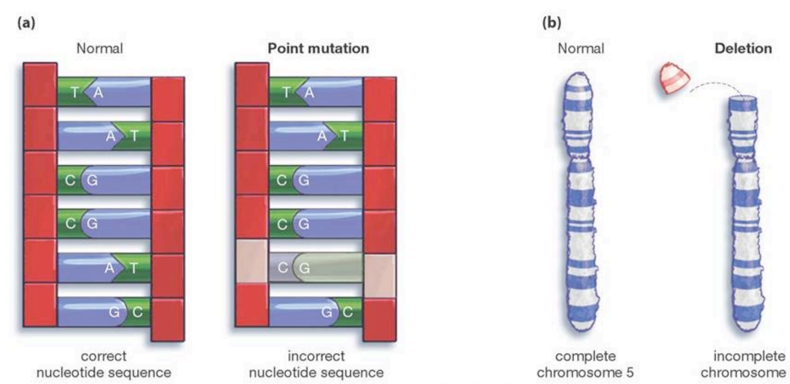
The Hardy-Weinberg Theorem tells us that sexual reproduction and events associated with it (meiosis, mixing of alleles, etc.) will NOT change the genetic structure of future generations, if certain assumptions are met.

Assumptions:

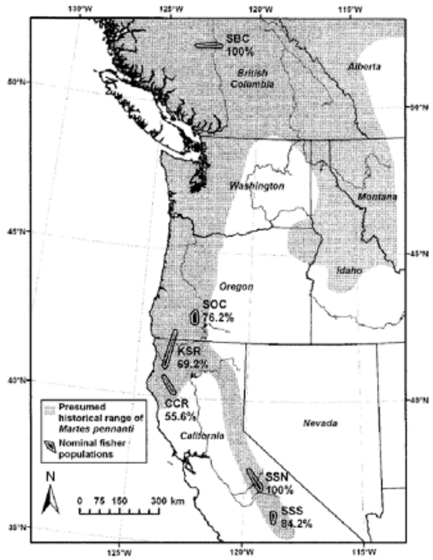
- no mutations (if they do, mutational equilibrium must exist)
- no gene flow among populations
- no genetic drift
- random mating; every individual must have an equal chance of mating with every other individual
- large population size

If these conditions are met, evolution will not occur. Very few, if any, populations actually meet these assumptions. So, **most populations are evolving**.

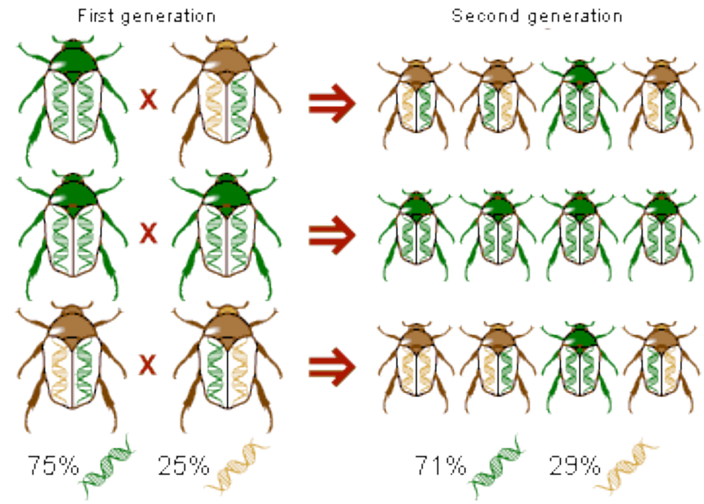
Genetic Change



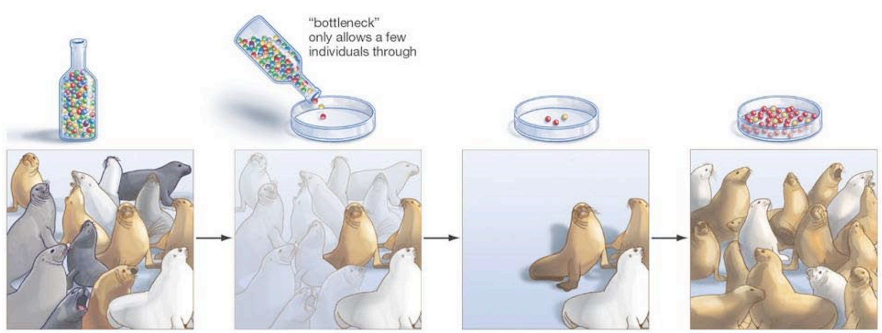
Gene Flow



Genetic Drift



Bottleneck Effect

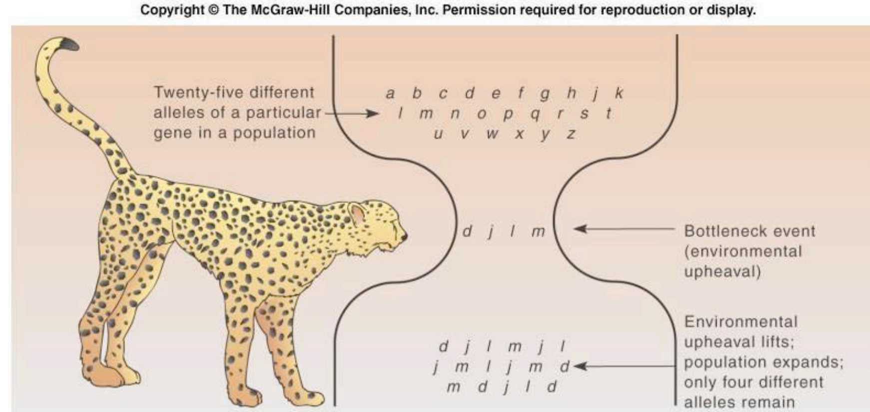


Original population, original allele frequency.

Hunting of seals in late 1800s greatly reduced population size.

Surviving population had different allele frequency and little genetic diversity.

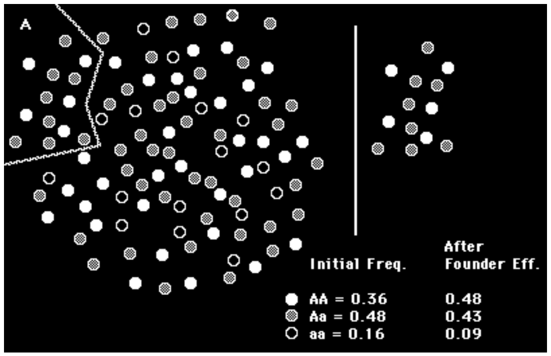
This different allele frequency is reflected in today's population.



(b)

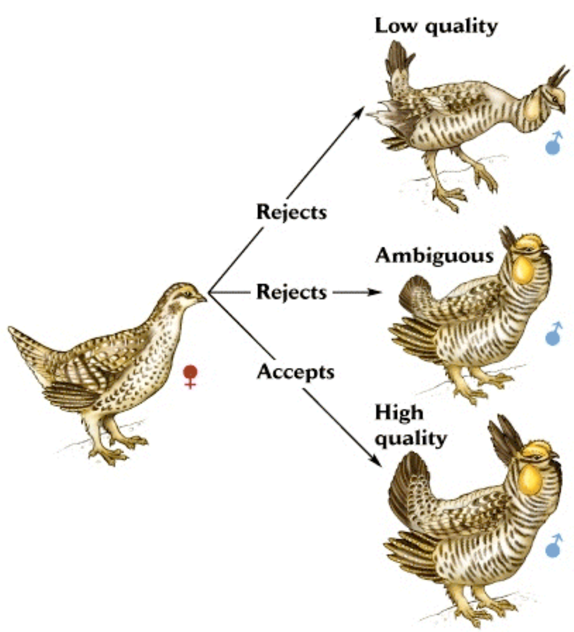
Founder Effect

- A subset of the population becomes isolated and does not represent the same allele frequency as the original population.

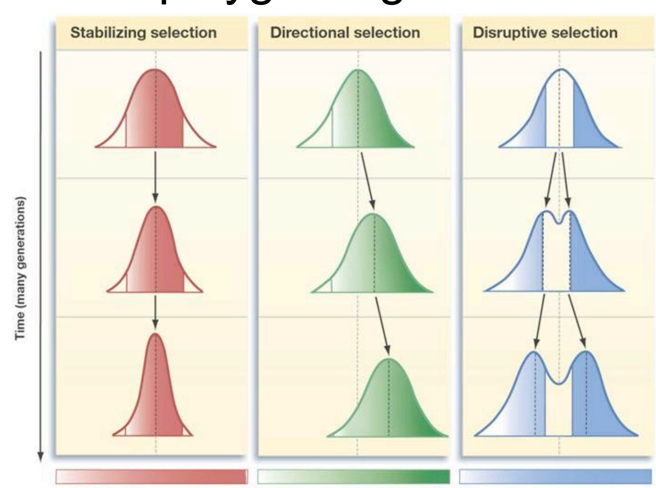


http://tidepool.st.usm.edu/crswr/founder.html

Nonrandom Mating: Sexual Selection



3 Modes of Selection: polygenic genes



Range of a particular characteristic (in this instance, lightness or darkness of coloration)

A flood occurs in an area inhabited by a population of mice. Many of the mice die, but a few with a mutation of webbed feet are able to swim to safety. Over the next couple of generations, most mice have webbed feet. The evolutionary mechanism that best explains this shift in the population would be:

A. Disrupted gene flow
B. Point mutation of the DNA
C. Founder's effect
D. Bottleneck effect

What is a Species?

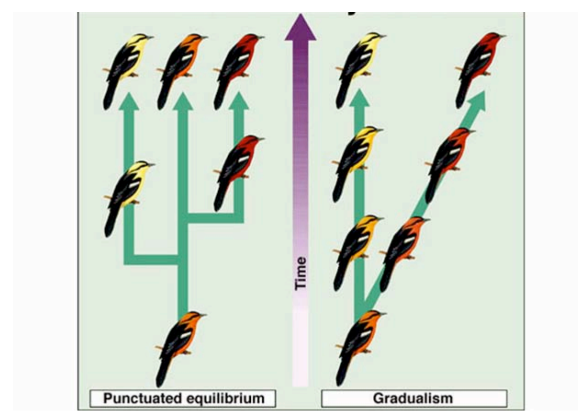
Why is species identification important?

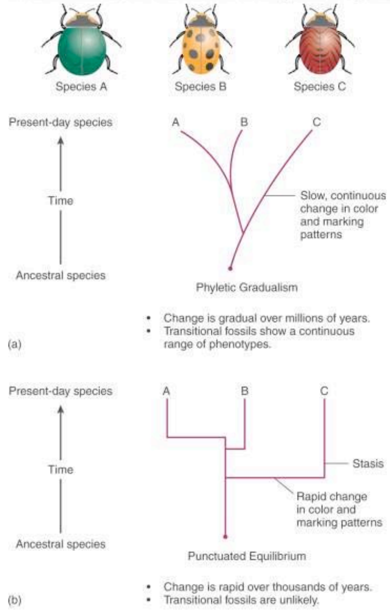
Black-tailed Gnatcatcher

California Gnatcatcher

Speciation

- A new species from an existing species





Modes of Speciation

- Allopatric Speciation
- Sympatric Speciation
- Adaptive Radiation
- Other modes

Allopatric Speciation

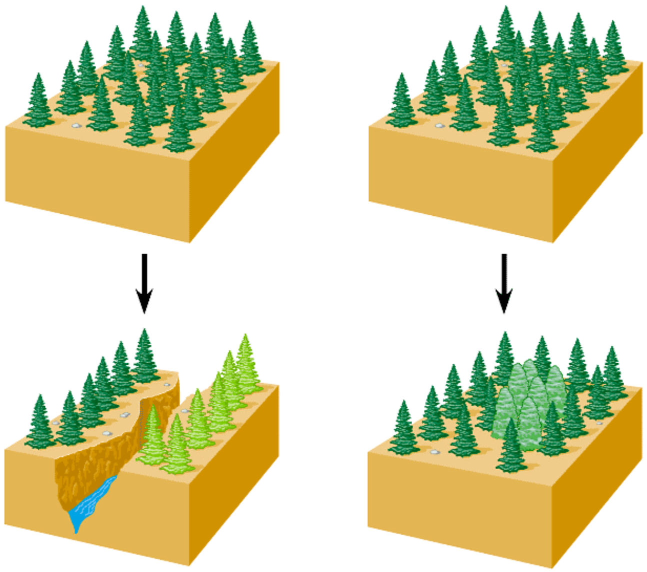
Sympatric Speciation

apple maggot flies

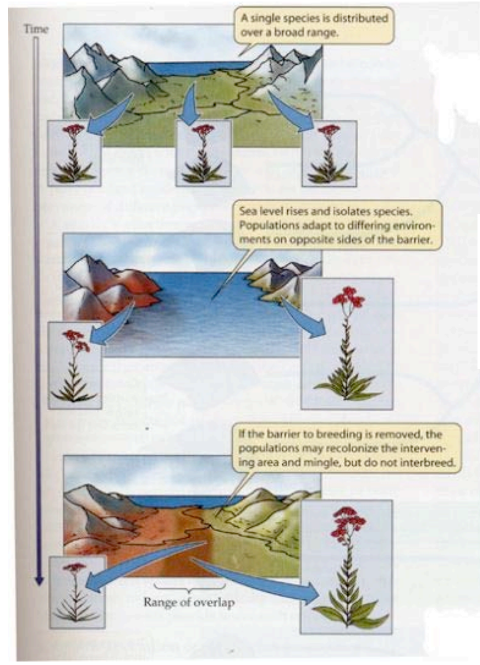
Apples (introduced)

Hawthorns (native)

Gene flow has been reduced between flies that feed on different food varieties, even though they both live in the same geographic area.

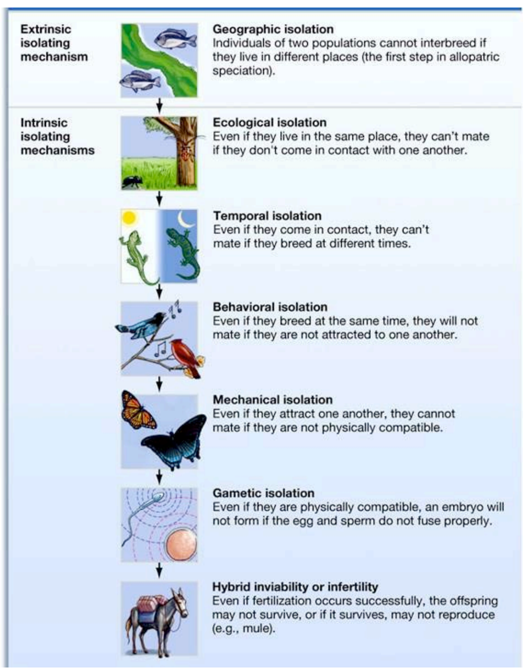


(a) Allopatric speciation (b) Sympatric speciation

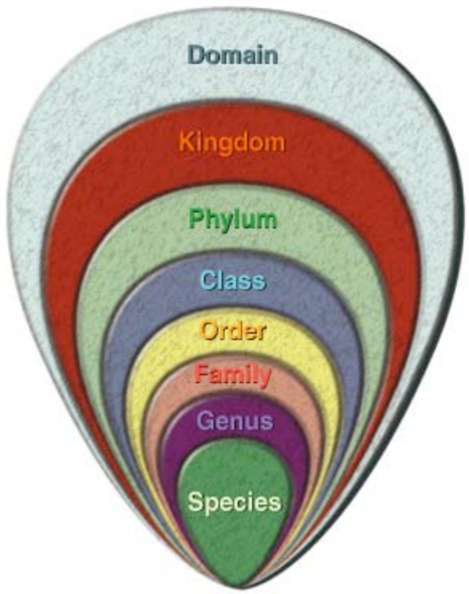


What type of speciation is occurring?

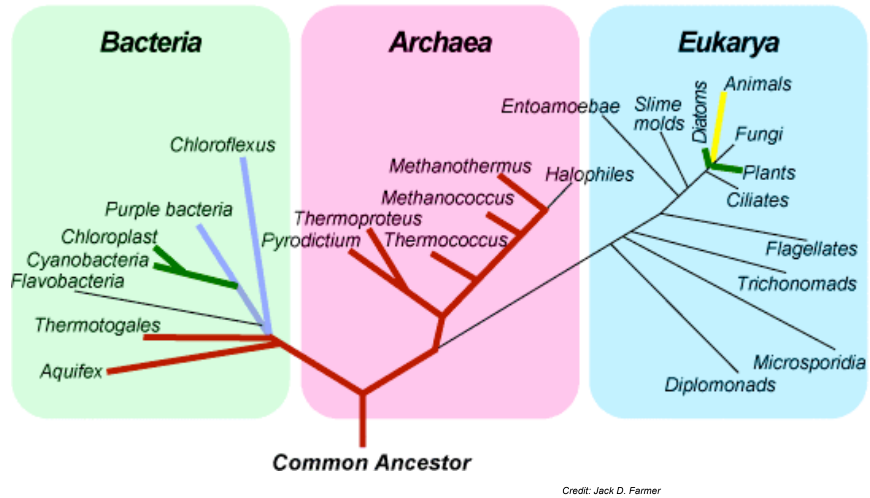
Reproductive Isolation Mechanisms



Extra slides follow…



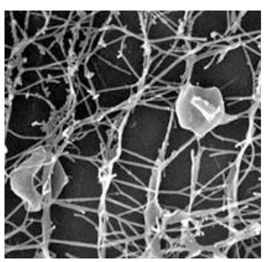
Domains of Life



Domain Archaea

Halophiles: salt loving

Extremely High Temperatures (80-113°C)



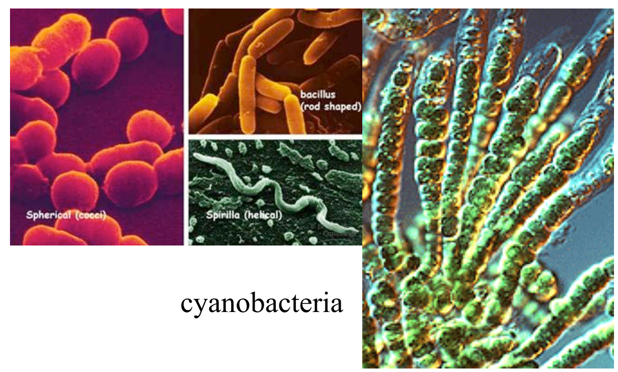
Pyrodictium

Pyrolobus (113C)

© 1997 R. Rachel

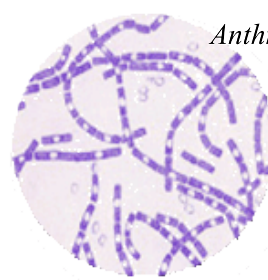
Other Archaea produce methane.

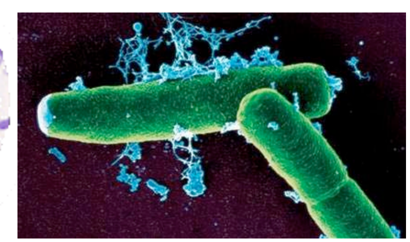
Domain Bacteria



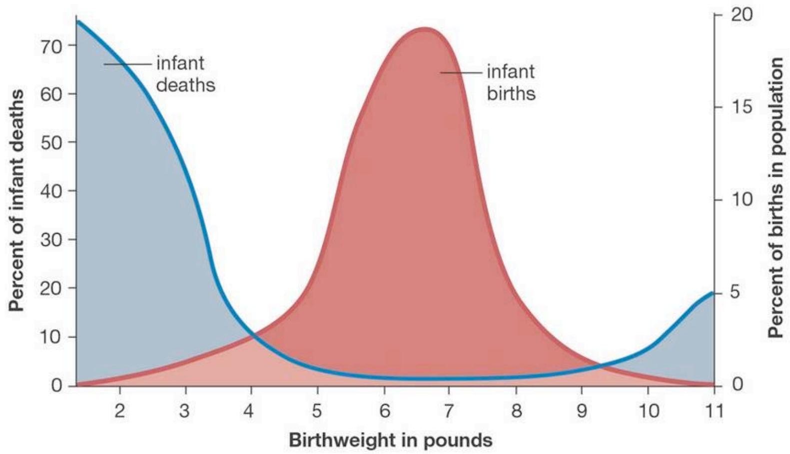
cyanobacteria

Anthrax

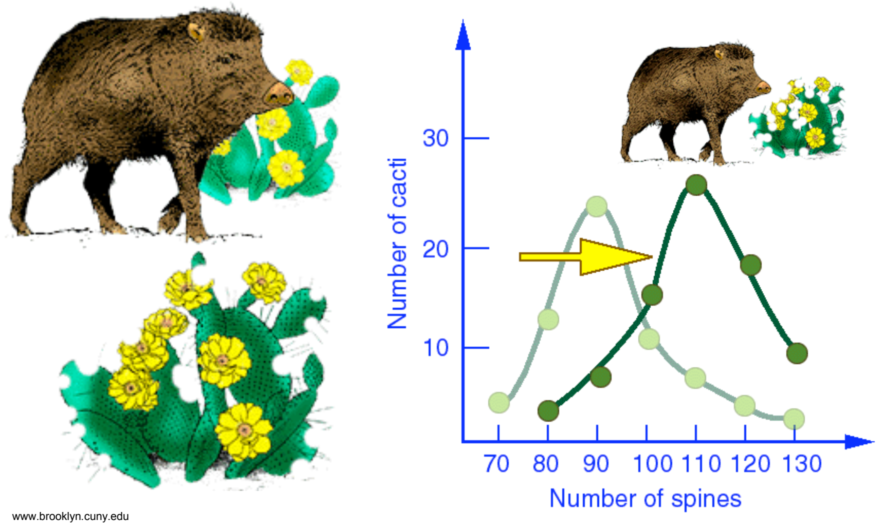




Stabilizing Selection



Directional Selection



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Disruptive Selection