ECOLOGY and DIVERSITY OF LIFE

Ecology

- Ecology is the study of life in the environment, as well as how all factors of the living and non-living world interact
- Earth is an elaborate, interconnected system
- Because of this, we are concerned with the health of all parts of the world

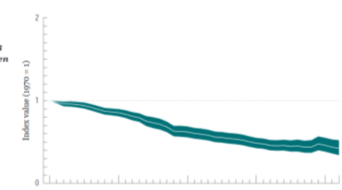
Diversity

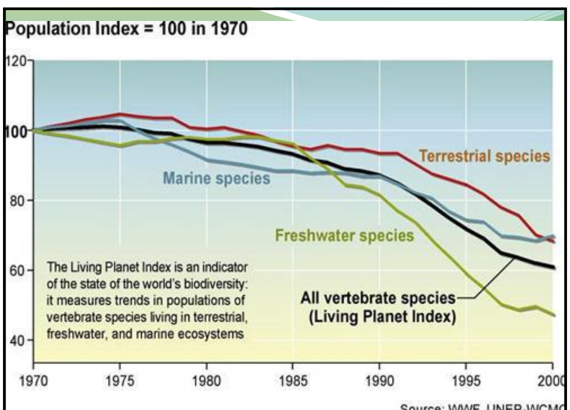
- Much of ecology focuses on Earth's **biodiversity**
- Biodiversity: the sum total of all life on Earth
  - Variations in ecosystems and habitats
  - Number of different species and their abundance
  - Genetic variation within each species
- Biodiversity has both intrinsic and extrinsic value and is worth conserving
  - Used to learn more about ourselves and our world
  - Potential source of resources
  - Intrinsic beauty/happiness

Global Declines in Biodiversity

- Currently in sixth mass extinction
- Wild and domesticated species
- Ecosystem functions down

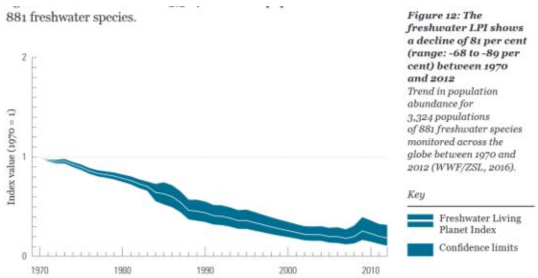
Figure 2: The Global Living Planet Index shows a decline of 58 per cent (range: -48 to -66 per cent) between 1970 and 2012
Trend in population abundance for 14,152 populations of 3,706 species monitored across the globe between 1970 and 2012. The white line shows the index values and the shaded areas represent the 95 per cent confidence limits surrounding the trend (WWF/ZSL, 2016).





Since the last *Living Planet Report*, 668 species and 3,772 different populations have been added (Figure 3). Representation of marine species data, particularly fish, has increased in the latest LPI dataset. However, there are still major geographic gaps in the data, largely in Central, West and North Africa, Asia and South America. Furthermore, the dataset is currently limited to populations of vertebrate species. Methods to incorporate invertebrates and plants are now in development.

Figure 3: The distribution of locations providing data for the Living Planet Index
Map showing the location of the monitored populations in the LPI. New populations added since the last report are highlighted in orange (WWF/ZSL, 2016).



Building Indices and Measuring Biodiversity…

- Much of our data relies on sampling and counting—this can be difficult and potentially inaccurate!
  - LPI currently only has vertebrate species—good proxy, but limits understanding of trends
- Generally to analyse biodiversity you must:
  - Collect organisms
  - Mathematically analyse diversity from sampled results

Sampling Techniques

- Sampling is random or systematic
  - Random is used when distribution of species seems random or not patterned
  - Systematic is used when conditions change—often in areas with ecological gradients like altitude, distance from a body of water, etc.

Quadrat Sampling

- Square frame that can determine species frequency (average number of organism in a total area) and species density (number of organisms per unit of area)

Mark Release Recapture

- Capture as many organisms as possible
- Tag in a non-harmful way
- Allow caught organisms to redistribute in their environment
- Recapture a large number of organisms
- Estimate the population with:
  - <u>(Total initial sample) x (Total second sample)</u>
    (Number marked in second sample)

Simpson's Index of Diversity

- n is the total number of organisms of a particular species
- N is the total number of organisms of all species

$$D = 1 - \left(\Sigma \left(\frac{n}{N} \right)^2 \right)$$

Simpson's Index of Diversity

- Use quadrat sampling to find populations of multiple species in a given ecosystem
- Calculate n/N for each species, square each value, add them up, and subtract from 1
- Values range from 0 to 1. Close to 0 means low diversity and close to 1 means high diversity
- Useful when you cannot ID to species but can acknowledge that there are different species present

$$D = 1 - \left(\Sigma \left(\frac{n}{N} \right)^2 \right)$$

Systematic Sampling

- Often relies on **transects**
  - Line transect: string a line through an ecosystem and note organisms at regular points along the line
  - Belt transect: uses a quadrat at regular intervals—more accurate

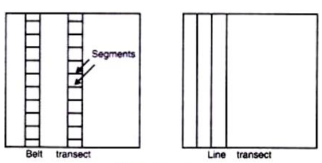
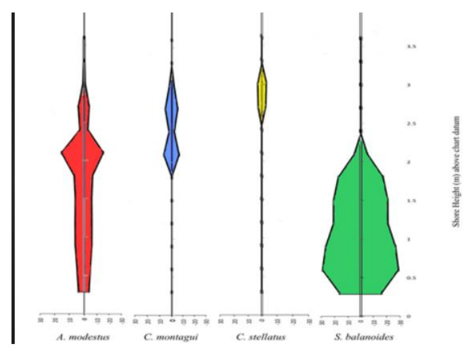


Fig. 6.8. Transects

Kite Diagrams



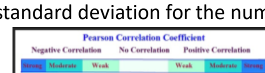
Correlation Statistics

- Once you have obtained observational data, you must determine if diversity if correlated to your independent variable (environment, abiotic factors, etc)
- Pearson's correlation coefficient
- Spearman's rank correlation coefficient
- Both are used in ecology studies to see if two populations are correlated with one another, so we will look at populations P and Q for examples…

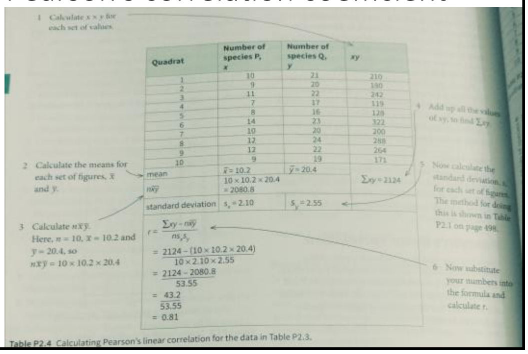
Pearson's correlation coefficient

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{n\, s_x\, s_y}$$

- *r* is the correlation coefficient
- *x* is the number of species P in a quadrat
- *y* is the number of species Q in the same quadrat
- *n* is the number of readings (samples)
- *x bar* is the mean number of species P
- *y bar* is the mean number of species Q
- s_x is the standard deviation for the numbers of P
- s_y is the standard deviation for the numbers of Q



Pearson's correlation coefficient



1 Calculate $x \times y$ for each set of values.

Quadrat	Number of species P, x	Number of species Q, y	xy
1	10	21	210
2	9	20	180
3	11	22	242
4	7	17	119
5	8	16	128
6	14	23	322
7	10	20	200
8	12	24	288
9	12	22	264
10	9	19	171
mean	$\bar{x} = 10.2$	$\bar{y} = 20.4$	
$n\bar{x}\bar{y}$	$10 \times 10.2 \times 20.4 = 2080.8$		$\sum xy = 2124$
standard deviation	$s_x = 2.10$	$s_y = 2.55$	

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{n s_x s_y} = \frac{2124 - (10 \times 10.2 \times 20.4)}{10 \times 2.10 \times 2.55} = \frac{2124 - 2080.8}{53.55} = \frac{43.2}{53.55} = 0.81$$

2 Calculate the means for each set of figures, $\bar{x}$ and $\bar{y}$.

3 Calculate $n\bar{x}\bar{y}$. Here, $n = 10$, $\bar{x} = 10.2$ and $\bar{y} = 20.4$, so $n\bar{x}\bar{y} = 10 \times 10.2 \times 20.4$

4 Add up all the values of xy, to find $\sum xy$.

5 Now calculate the standard deviation, s, for each set of figures. The method for doing this is shown in Table P2.1 on page 498.

6 Now substitute your numbers into the formula and calculate r.

Table P2.4 Calculating Pearson's linear correlation for the data in Table P2.3.

Spearman's Rank Correlation

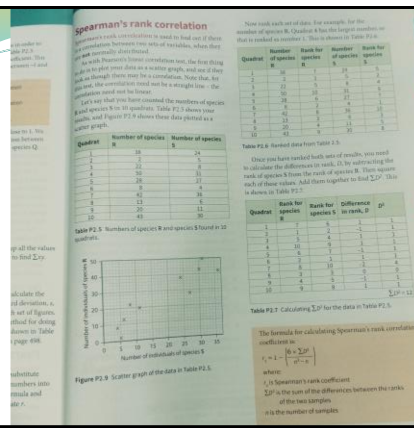
$$r_s = 1 - \frac{6(\sum d^2)}{n(n^2-1)}$$

- Used when the data appears to have a relationship but it is not linear
- Plot data as a scatter graph
- Rank each species data in order of size so that the largest population is ranked 1, the second largest is 2, etc.
- Once you have ranked both data sets, calculate the differences in rank, *D*, by subtracting rank of species S from rank of species R
- Square each *D* and add them all together, then plug and chug

Spearman's Rank Correlation

$$r_s = 1 - \frac{6(\sum d^2)}{n(n^2-1)}$$

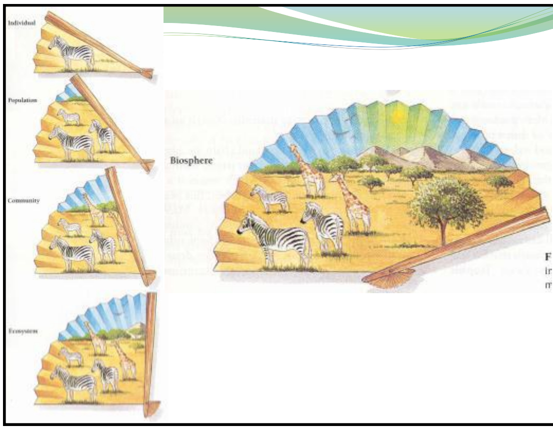
- r_s is Spearman's rank coefficient
- $\sum D^2$ is the sum of the squared differences between the species groups ranks
- *n* is the number of samples
- We multiple by 6 because why not?



That's the math. Take a breather.

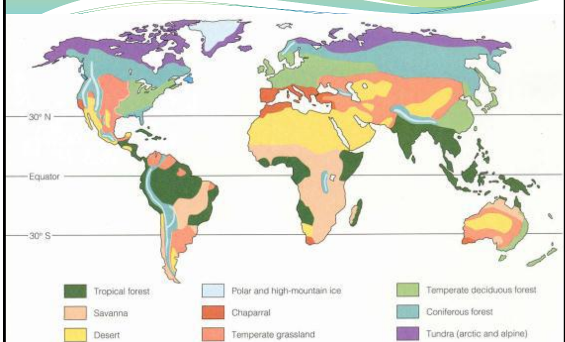
Organization of Life

- Habitat: wherever an organism lives
- To keep systems organized, we describe life on Earth in a string of hierarchies:
- Species → Population → Community → Ecosystem → Biome → Biosphere
- Every organism has a **niche**, or a role in the environment



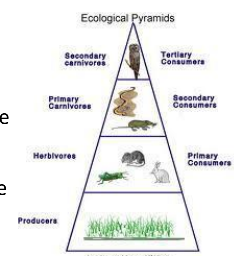
Biomes

- Large zones of land or aquatic habitat with similar climate (periodic temperature and precipitation), organisms, and soils
- Caused by climate bands, wind currents, and cycling of the atmosphere
- Six major terrestrial biomes: Tundra, taiga, temperate deciduous forest, grassland, tropical rainforest, desert
  - Some biomes are more fragile than others (tundra, TRF)
  - Some biomes are more diverse



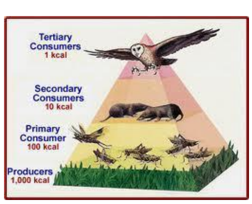
Energy Flow

- Energy comes from an initial source (a producer or autotroph) and flows to organisms that cannot produce their own energy (a consumer or heterotroph)
- Most energy on Earth from the process of photosynthesis
- Energy supplied to animals by the process of cellular respiration



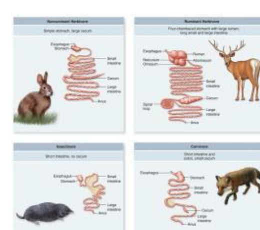
Energy Flow

- Energy efficiency depends on how it is transferred and where it comes from
- Energy tiered in “trophic levels” and often arranged in pyramids
- “Rule of 10” states than on average, only about 10% of energy transfers from one level to the next



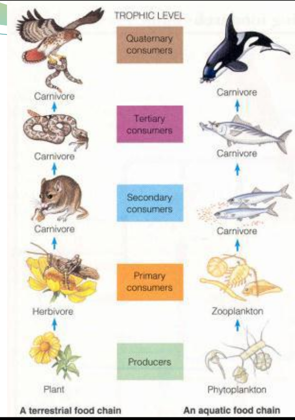
Energy Flow

- Energy efficiencies depend also on procurement and transfer:
  - Herbivores more efficient procurers of food but get less energy from what they consume
  - Predators get more energy from their food, but have to invest more energy into obtaining it



Food Chains

- Show order of energy transfer
- Simple link of one organism to the next
- Arrows show direction of energy flow: point from what is being eaten/consumed to what is doing the consuming
- All chains start with the sun
  - Each day 10^{19} kcal of solar energy = 100 million atomic bombs



Levels of Feeding

- Producers
- Primary consumers
- Secondary consumers
- Tertiary consumers
- Quaternary consumers

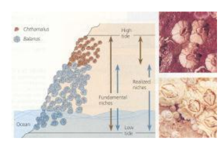
- Detritivores: feed on decomposing matter, often at all or many levels of the food chain

Food Webs

- More accurate representation of energy transfer
- As ecosystems are interactive, food chains aren't always as simple as they seem
  - Example: Alligator can be a top predator OR consumed by a secondary consumer

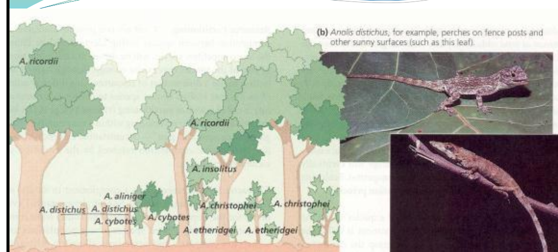
Organismal Interactions

- Organisms in an ecosystem interact in dynamic and diverse ways
- Primarily driven by **competition**
- Competition is what ultimately drives evolution



Resource Partitioning

- Competition over resources is what leads to partitioning
  - Rather than compete, organisms segregate into different niches
  - Niches are determined based on partitioning
  - Can lead to adaptive radiation in extreme instances→ evolution!!



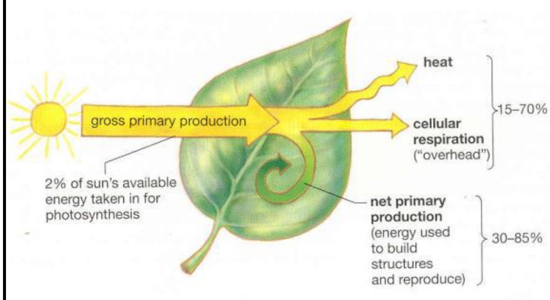
(a) Seven species of *Anolis* lizards live in close proximity at La Palma in the Dominican Republic. The lizards all feed on insects and other small arthropods. However, competition for food is minimized because each lizard species perches in a certain microhabitat.

(b) *Anolis distichus*, for example, perches on fence posts and other sunny surfaces (such as this leaf).

(c) In contrast, *A. insolitus* usually perches on shady branches.

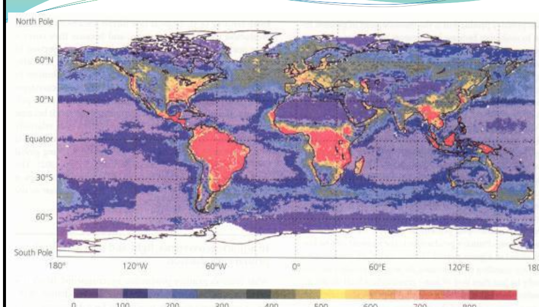
Productivity

- Solar (or geothermal) energy converted to chemical energy = Gross Primary Productivity
- Energy available for the next trophic level after respiration, etc. is subtracted= Net Primary Productivity
- This will tie in to photosynthesis later… don't forget!



PP varies depending on

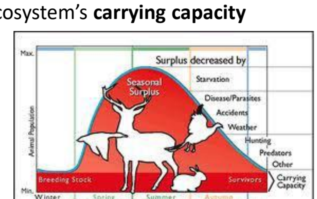
- Amount of CO_2
- Amount of light
- Minerals available
- Amount of water
- Temperature – roughly doubles each 10°C
- All of the above are also photosynthetic *limiting factors*



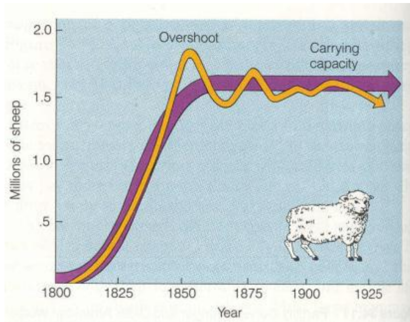
Availability of Resources and Competition Leads to Specific Population Interactions!

Populations

- Every ecosystem has a limited amount of energy and resources, so populations cannot grow indefinitely
- The maximum amount of organisms in an area is that ecosystem's **carrying capacity**



S-shaped curve



Carrying Capacity

- Different organisms have evolved differently to combat competition and carrying capacity

r and k Strategists

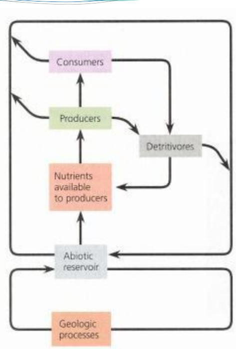
- r-strategists: Give birth to many offspring which mostly die early in life
- k-strategists: Give birth to a few offspring, care for them, many reach adulthood/sexual maturity

Limiting Factors

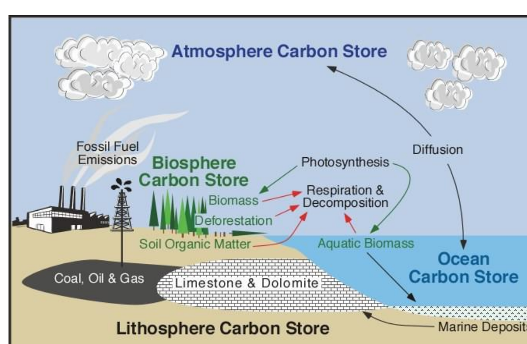
- Ultimately what limits the size of populations are limiting factors
  - Either living factors (biotic) or nonliving (abiotic)
  - Can be density-dependent or density-indpendent
  - Can be devastating or regulatory

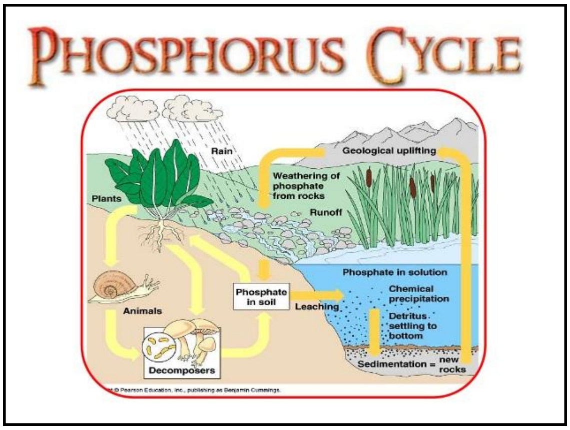
Matter Recycling

- Matter can neither be created nor destroyed, so all matter on Earth cycles through various phases
- Predictable patterns of cycling are what create and dictate Earth's biogeochemical cycles
  - Biogeochemical cycles typically have both abiotic and biotic components

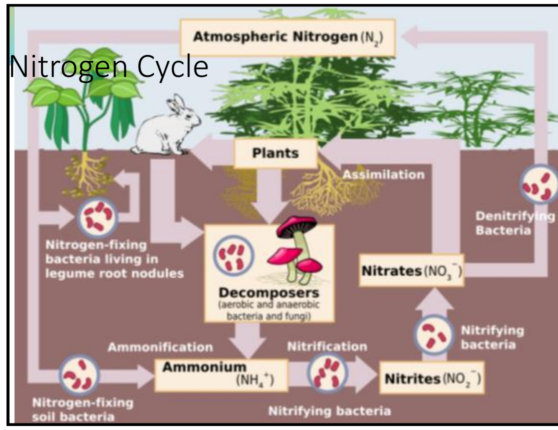


Carbon Cycle





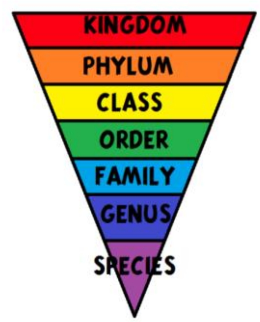
Nitrogen Cycle

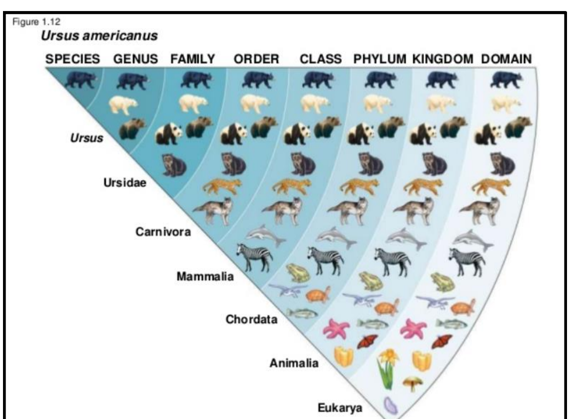


The Diversity of Life

Life is ordered in a hierarchy

- Domain
- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- Species

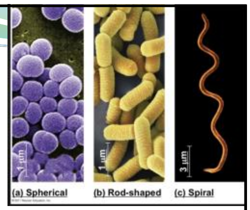




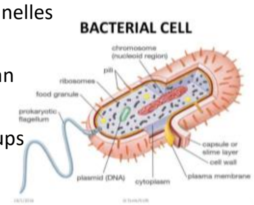
Domains

- Splits all life into three groups, two prokaryotic and one eukaryotic:
- Archaea: extremophile prokaryotes—these weird organisms are likely more similar to us than bacteria are
- Bacteria: single celled, prokaryotes—remember chapter 1
- Eukarya: Eukaryotic organisms with organelles

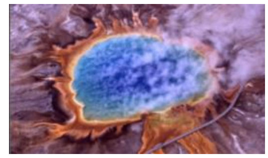
Bacteria

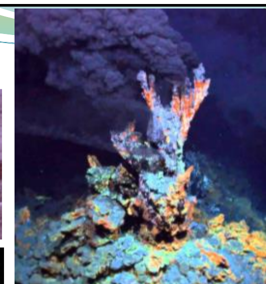


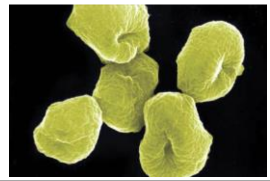
- No nucleus
- Circular, naked chromosome
- Plasmids often present
- No membrane bound organelles
- 70s ribosomes
- Cell wall with peptidoglycan
- Binary fission (no mitosis)
- Unicellular or in small groups



Archaea





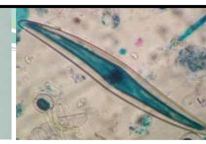


- Characteristics are very similar to bacteria but slight differences in ribosomes (still 70s but similar to eukarya ribosomes in structure) and cell wall (no peptidoglycans)

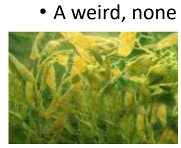
The Four Kingdoms of Eukarya

- Protoctista = Protists. Called Kingdom “Protista” in the States
- Fungi = true mushrooms, slime molds, molds, shelf fungi
- Plantae= Plants
- Animalia = Animals
- All have:
  - Cells with nucleus and membrane bound organelles
  - Linear chromosomes with histone proteins
  - 80s ribosomes except in chloroplasts and mitochondria
  - Huge diversity of forms
  - Mitotic division of cells with both sexual and asexual repro

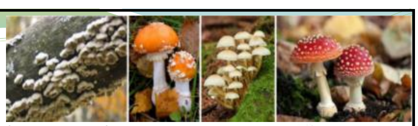
Protoctista



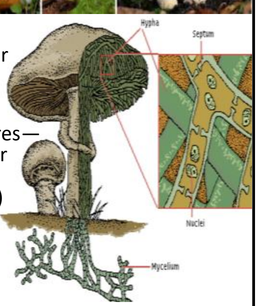
- Eukaryotic
- Mostly single celled or exist as communal organisms
- Animal like without cell walls = Protozoa
- Plant like with cellulose cell walls = Algae
- A weird, none and all of the above Kingdom



Fungi



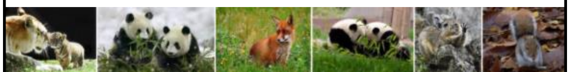
- Eukaryotic heterotrophs
- Can be single or multicellular
- Reproduce via spores
- Simple body with threadlike hyphae which produce spores—hyphae may be unicellular or clumped together in fruiting bodies (mushrooms)
- Cell walls made of chitin
- Never have cilia or flagella



Plantae

- Multicellular eukaryotes (have differentiated tissues)
- Photosynthetic autotrophs, though some supplement photosynthesis with other nutrition (carnivorous plants—usually for nitrogen)
- Cells have large, often permanent vacuoles
- Cell walls with cellulose—may come in multiple layers
- Cells might have flagella (certain pollen gametes)

Animalia



- Multicellular eukaryotes
- Many differentiated cells to form tissues and organs
- Cells are obligate heterotrophs
- Cell vacuoles are small and temporary (lysosomes)
- No cell walls
- Communication through a nervous system
- Cells can have cilia or flagella

Phylogenetic Tree of Kingdom Animalia

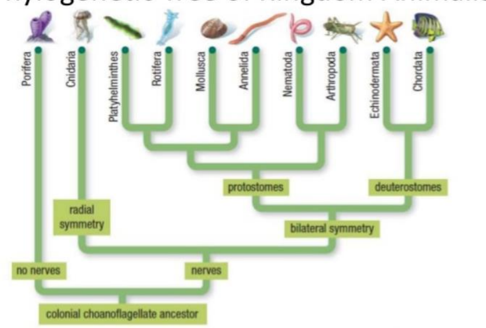
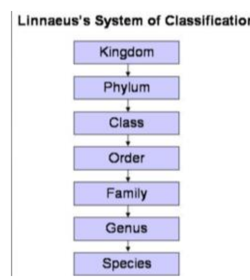


Figure 5 This phylogenetic tree of the Animal Kingdom is based on recent evidence from genetics and molecular biology. The tree shows 10 of the 17 animal phyla.

Linnaean Classification and Dichotomous Keys

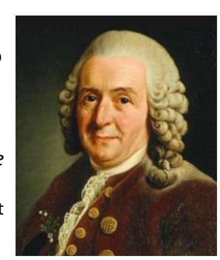
Organizing biology is all about hierarchies!

- Already talked about the 4 (6) kingdom system
- Each large group is split into smaller groups
- (Domain) → Kingdom → Phylum → Class →Order → Family → Genus → Species



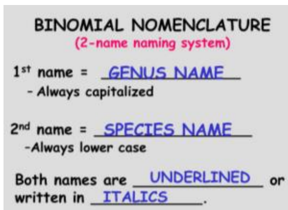
Carl Linnaeus

- Nobilized as "Carl Von Linne," he was a Swedish botanist who revolutionized the way scientists communicate about organisms
- Published the *Systema Naturae* in 1735
  - Widely hailed as one of the most important biological texts ever written



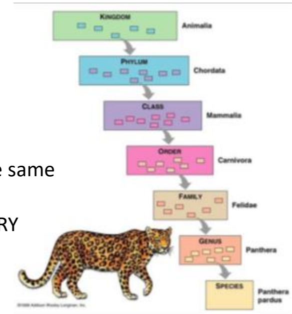
Binomial Nomenclature

- Every organism on Earth that is described by a scientist has two names (Bi-nomial)
  - Genus name: Larger group
  - Species name: specific to ability to inbreed



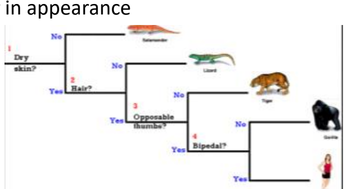
Why care about binomial nomenclature?

- Standardizes scientific discourse
- Enables scientists from different cultures to communicate about the same organism
- Common names are VERY unreliable!



Dichotomous Keys

- Series of two-condition questions used to identify organisms by morphological traits
- Based in the logic that genetically (and thus evolutionary hierarchically) similar organism are similar in appearance



Dichotomous Key For Leaves

1. a. Needle leaves	go to 2	
b. Non-needle leaves	go to 3	
2. a. Needles are clustered	Pine	
b. Needles are in singlets	Spruce	
3. a. Simple leaves (single leaf)	go to 4	
b. Compound leaves (made of "leaflets")	go to 7	
4. a. Smooth edged	go to 5	
b. Jagged edge	go to 6	
5. a. Leaf edge is smooth	Magnolia	
b. Leaf edge is lobed	White Oak	
6. a. Leaf edge is small and tooth-like	Elm	
b. Leaf edge is large and thorny	Holly	
7. a. Leaflets attached at one single point	Chestnut	
b. Leaflets attached at multiple points	Walnut