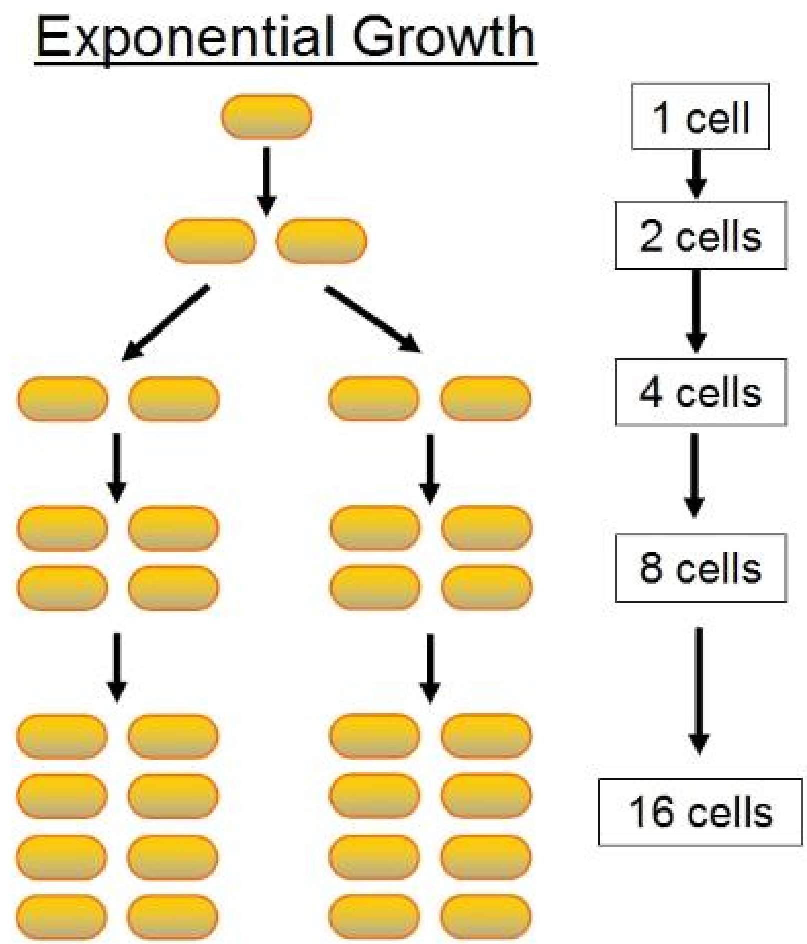
Models Predict Patterns of Population Growth

- Population sizes fluctuate as new individuals are born or immigrate and die or emigrate.
  - Some population sizes stay relatively constant while others change rapidly, even explosively.
    - Ex: Consider a bacteria that, under ideals conditions, every 20 minutes.
      - There would be two bacteria after 20 minutes
      - There would be four bacteria after 40 minutes
      - There would be eight bacteria after 60 minutes
      - In 12 hours, there would be 70 billion cells!
        - In 36 hours, there would be a foot-deep layer over the entire Earth!



Population Size Calculation

- **Assuming immigration and emigration rates are equal, a <u>population's size changes based on the number of deaths and the number of births</u> over a certain amount of time.**
  - N = population size
  - B = # of Births/time
  - D = # of Deaths/time
  - t = time

d = change

$$\frac{dN}{dt} = B - D$$

Units for dN/dt = change in individuals / particular period of time

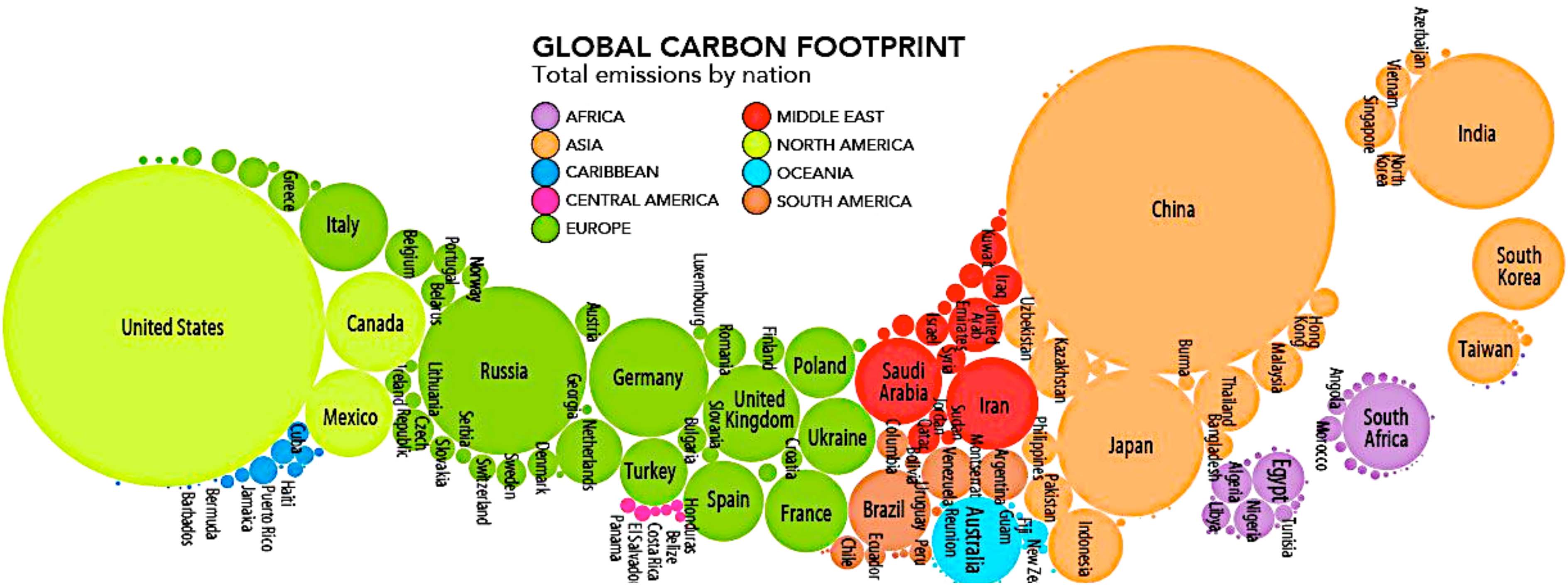
Per Capita Population Parameters

- Often it is useful to express population data on birth and death rates on a per capita *(per person)* basis.
  - Makes it easier to compare populations of different sizes.
    - This standardizes, across different population sizes, by expressing population growth parameters on a per person basis.
      - Example
        - If you know there are 5 births in a population in a year, that doesn't tell you much about what is really going on in the population. Is 5 a lot or a little?
          - This answer depends on how many are already in the population.

If you know what is happening on a per person basis though, you can understand if there is a lot of births or little in the population better and more easily compare it to other populations of differing sizes.

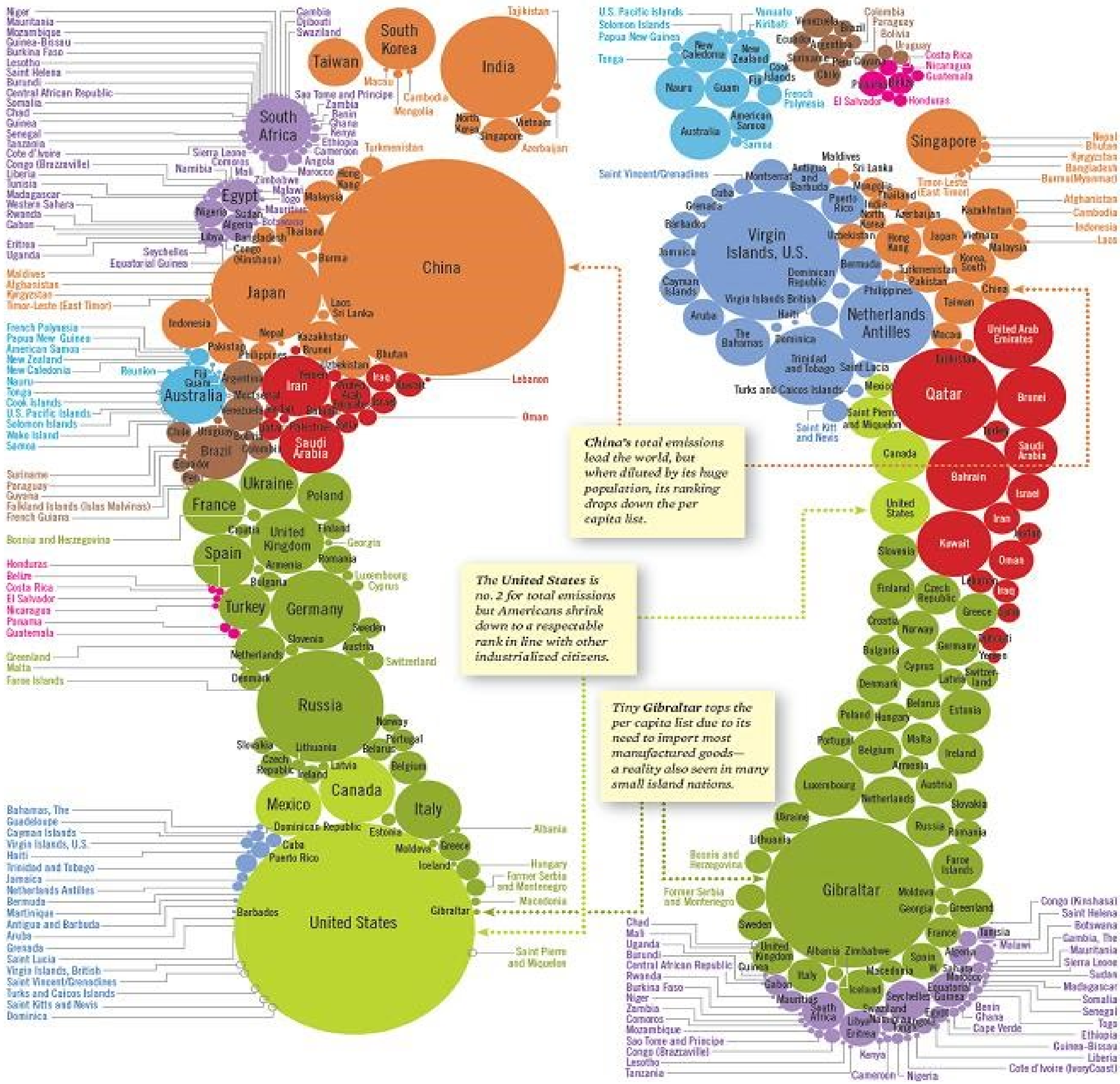
Ex: Analyzing Carbon (CO_2) Emissions

- **Comparatively, the U.S. produces a large amount of carbon dioxide waste through the burning of fossil fuels.**
  - **Partly this makes sense since the U.S. has the third largest population size in the would.**
    - **But, does each individual in the U.S. produce on average more carbon emission's waste than each individual in a smaller country? or in a less economically-developed country?**
      - **Just knowing the total amount of carbon emissions doesn't capture other important aspects of carbon emission**



Total Carbon Emissions by Nation

Total Carbon Emissions Per Capita



Ex: Total # of Covid-19 Deaths vs. Average # of Covid-19 Deaths Per 100,000 people

- Calculating a value to compare in which the denominator is the same for all populations *(averaging the # of deaths per organism or in this case per 100,000 organisms)* allows one to compare the # of deaths among groups of the same size no matter how big or small the total population sizes are.
  - India has much larger in population than the U.S. and yet has had way fewer overall deaths, which is curious. However, the U.S. has a population that is much larger Peru though so it may not stand out as curious that the U.S. had more deaths than Peru.
- When groups of 100,000 are compared though, it is clear that India experienced much fewer deaths than the U.S. while Peru experienced many more!
  - Now, one can investigate why that may be the case?

Cases and mortality by country

COUNTRY	CONFIRMED	DEATHS ▼	CASE-FATALITY	DEATHS/100K POP.
US	103,802,702	1,123,836	1.1%	341.11
Brazil	37,076,053	699,276	1.9%	328.98
India	44,690,738	530,779	1.2%	38.46
Russia	22,075,858	388,478	1.8%	266.20
Mexico	7,483,444	333,188	4.5%	260.73
United Kingdom	24,658,705	220,721	0.9%	325.13
Peru	4,487,553	219,539	4.9%	665.84

Per Capita Birth and Death Rates

- To determine per capita birth of death rates, divide the absolute # of births (B) per time or deaths (D) per time by population size # (N).
  - Per capita birth rate
    - b = B/N (the unit for b = individuals / period of time * individuals)
  - Per capita death rate
    - d = D/N (the unit for d = individuals / period of time * individuals)

Per Capita Growth Rate

- The per capita population growth rate or per capita rate of increase is referred to as "r"
  - Signifies the average contribution of EACH individual makes to population growth
    - r_{max} = the maximum contribution each individual can make under ideal conditions

$$r = b - d$$ *(memorize this!)*

- When r = 0 = Population is not growing
- When r = - # = Population is shrinking
- When r = + # = Population is growing
  - The larger the # the faster it is growing or shrinking too.

Exponential Growth Model

- The rate of population increase under *ideal* or *near ideal* conditions is called exponential growth
  - Calculated using the simple equation:

$$\frac{dN}{dt} = r_{(max)}N$$

- dN/dt or G = growth rate of the population
  - the total number of new individuals added or lost per time interval
    - dN/dt is the CHANGE in population size over time
      - Negative value of dN/dt = identifies the # of individuals lost from the population in that time period
      - Positive value of dN/dt = identifies the # of individuals gained in the population in that time period

Exponential Growth Model

$$\frac{dN}{dt} = r_{(max)}N$$

- In the table, a population begins with 20 rabbits.
  - The growth rate (dN/dt) for this population, using $r = 0.3$, is shown in the right-hand column.
- **Note**: the larger the population size, the more new individuals are added during each time interval.
  - Graphing these data produces a J-shaped curve, which is typical of exponential growth.

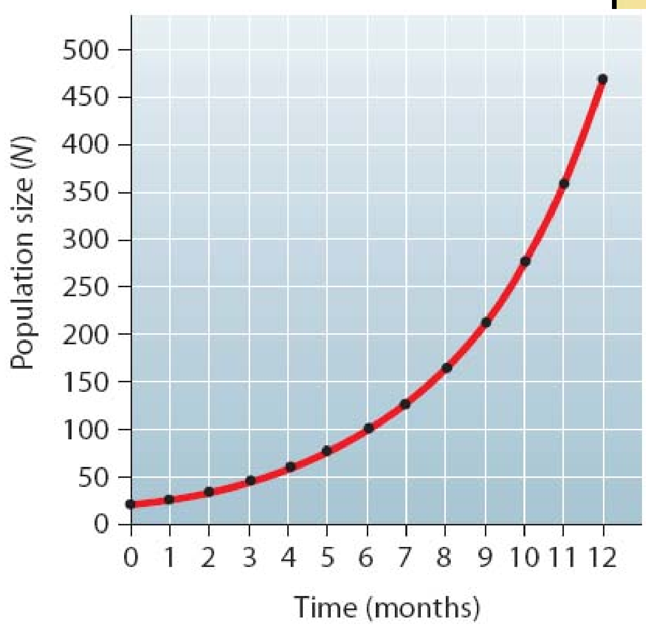


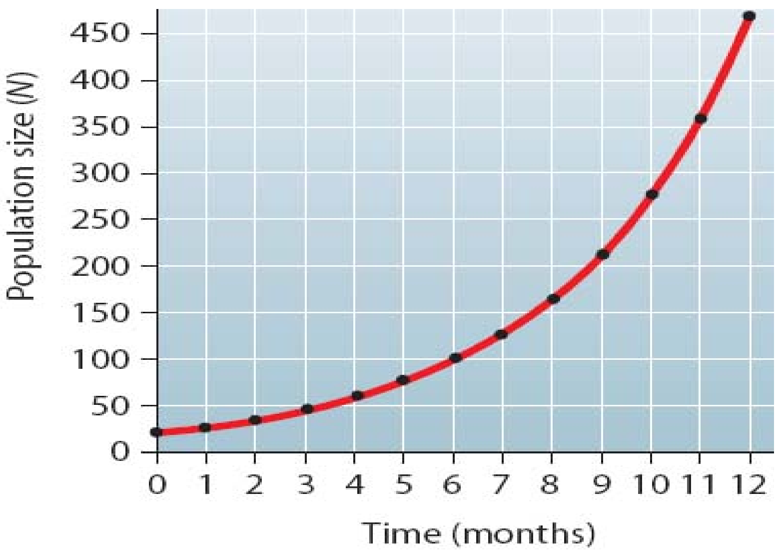
TABLE 36.4A EXPONENTIAL GROWTH OF RABBITS, $r = 0.3$

Time (months)	N	$G = rN$
0	20	6
1	26	8
2	34	10
3	44	13
4	57	17
5	74	22
6	96	29
7	125	38
8	163	49
9	212	64
10	276	83
11	359	108
12	467	140

Exponential Growth Model

$$\frac{dN}{dt} = r_{(max)}N$$

- The lower part of the J, where the slope of the line is almost flat, results from the relatively slow growth when N is small.
  - As the population increases, the slope becomes larger.

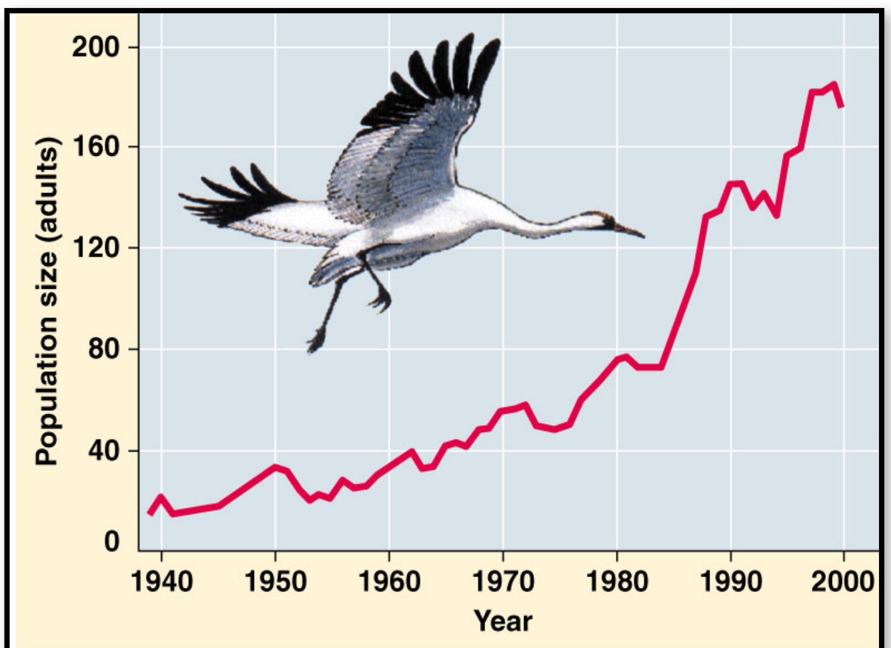


- The exponential growth model gives an idealized picture of unregulated population growth.
  - There is no restriction on the abilities of the organisms to live, grow, and reproduce.
    - Even elephants, the slowest breeders on the planet, would increase in population size exponentially if enough resources were available.
  - Obviously, no population—neither bacteria nor rabbits nor elephants—can grow exponentially indefinitely!!!

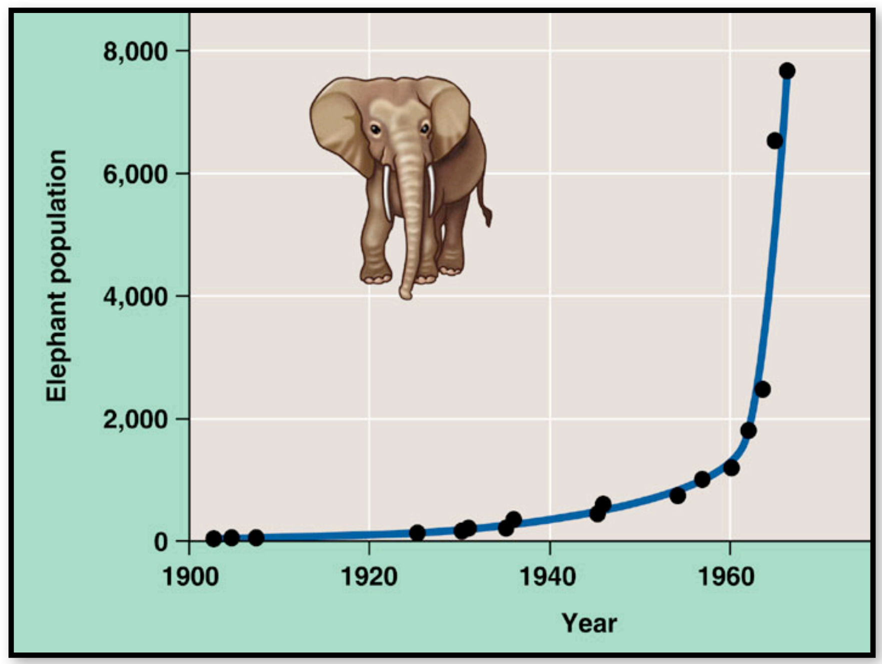
Exponential growth rate - J shaped Curve

- Characteristic of populations without **limiting factors**
  - Seen in populations introduced to a new environment or rebounding from a catastrophe
    - After approximately 60 years of exponential growth, the large number of elephants had caused enough damage to the park vegetation that a collapse in the elephant food supply was likely, leading to an end to population growth through starvation.

Whooping crane coming back from near extinction

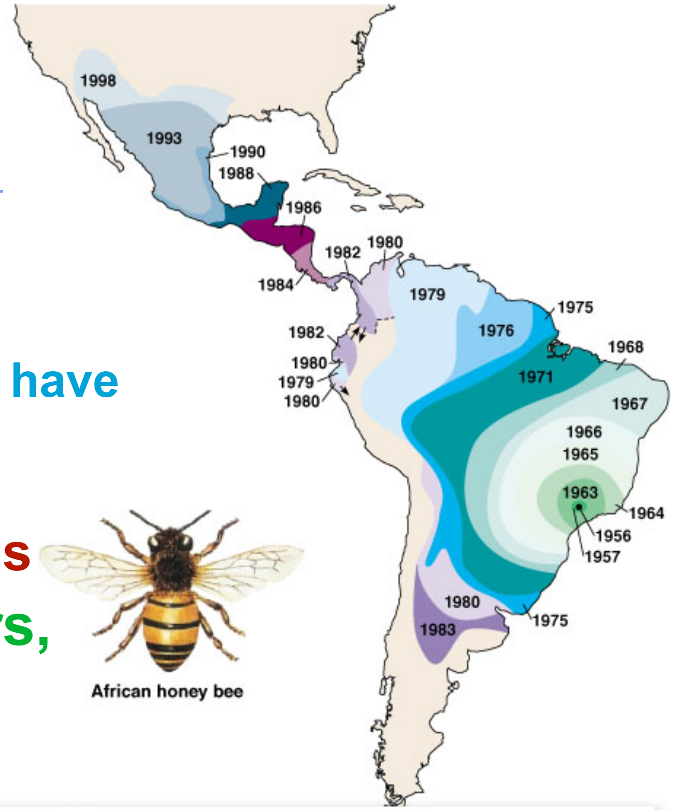


African elephant protected from hunting



Introduced species

- **Non-native species**
  - transplanted populations often grow exponentially in new areas (if the areas have suitable biotic and abiotic factors for the introduced species)
    - loss of natural population size controls
      - may experience lack of predators, parasites, competitors
  - May out-compete native species for resources
    - results in reduce biodiversity in the area
  - Examples
    - African honeybee
    - gypsy moth
    - zebra mussel
    - purple loosestrife



gypsy moth

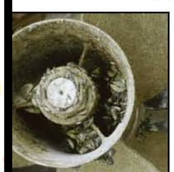
NOT WANTED

Zebra Mussel Outlaws

Threats to the West ~ Why Be Concerned?

Zebra mussels cause devastating impacts on municipal water systems, recreation and fisheries. Currently, they are widespread in Eastern USA and as far west as Oklahoma. We don't want these outlaws in California where they would rapidly reproduce and cause millions of dollars in damage to our water resources and recreation. We need your help to stop these mussels from entering our lakes, rivers and streams.

HOW COULD THESE OUTLAWS 'RIDE' HERE?



to boat hulls and

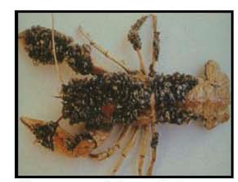
On infested recreational boats and commercial boat haulers from infested waters like the Mississippi River and Great Lakes.

HOW CAN WE ARREST THE SPREAD?

Learn how to identify zebra mussels (see sidebar).
Remove all aquatic plants and animals from boat, motor, trailer, and equipment.
Drain water from livewells, bilge, and motor.
Dispose of unwanted live minnows and worms in the trash.
Rinse boat and equipment with high pressure or hot water, especially if moored for more than a day, OR
Dry everything for at least 5 days.
Never launch watercraft with a suspected infestation.
Report sightings on watercraft or in a lake or river – note location, place mussel in a sealed container with rubbing (isopropyl) alcohol, and call the Zebra Mussel Watch Hotline, 1-888-840-8917.

Found only in freshwater. Small barnacle-like clams with dark and light colored stripes.

millions of dollars year to control in plants and water systems.



Cover crayfish and clams, and outcompete native species for food and habitat.

VOLUNTEER FOR A POSSE

Early detection is key to preventing and mitigating impacts of zebra mussels. If you would like to help as a volunteer monitor to protect your lake or river, please contact:

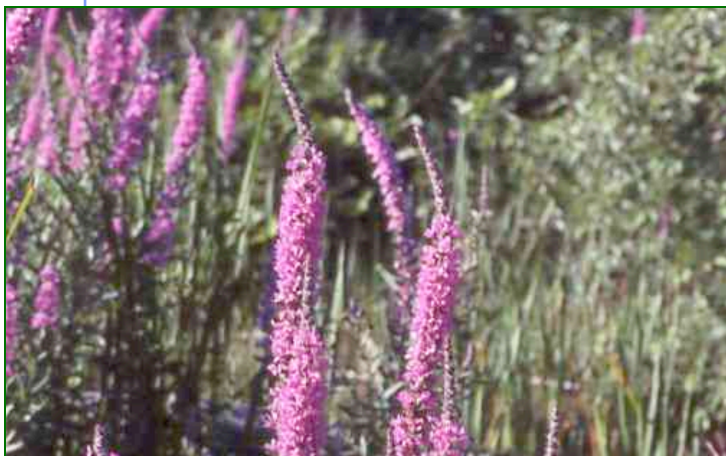
Zebra Mussel Watch Program
1 (888) 840-8917 (toll free)
mussel@water.ca.gov

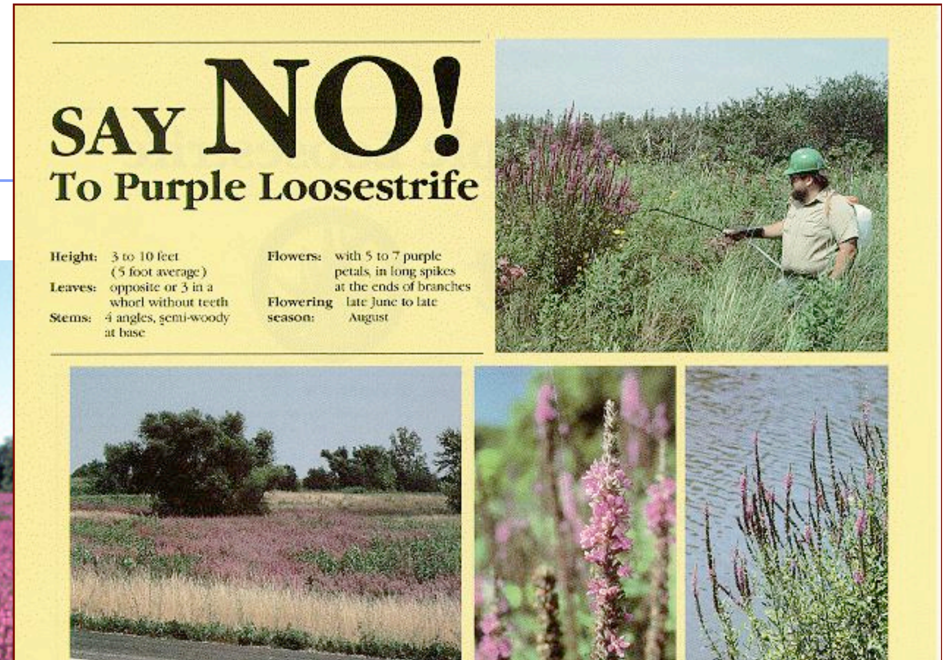
CALIFORNIA BAY-DELTA AUTHORITY

Zebra Mussel

- reduces biodiversity
- causes loss of food sources & nesting sites for native animals
- economic damage

Purple loosestrife





- reduces diversity
- loss of food & nesting sites for animals

Logistic rate of growth

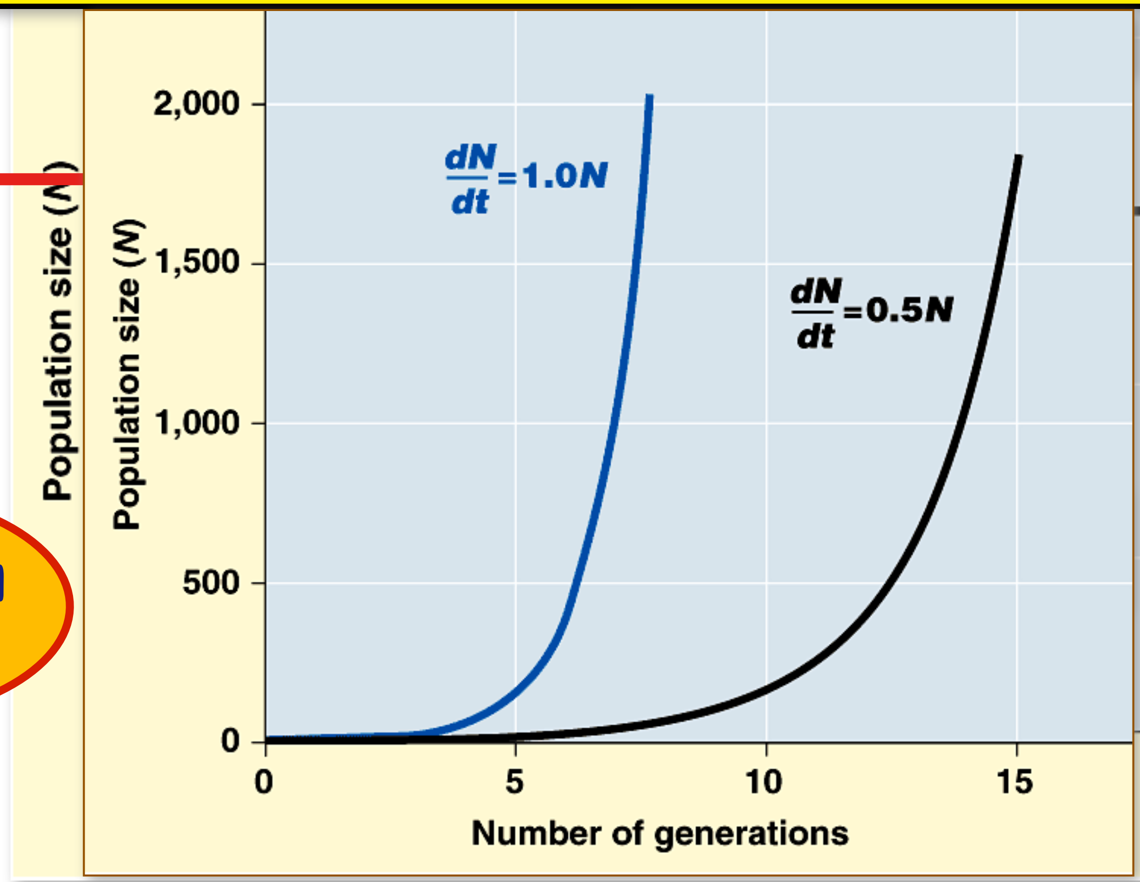
$$\frac{dN}{dt} = r_{max}N\left(\frac{K-N}{K}\right)$$

- Can populations continue to grow exponentially?

Of course not! In real life, biotic & abiotic resources are limited & organism interactions can affect the ability to expand in population size.

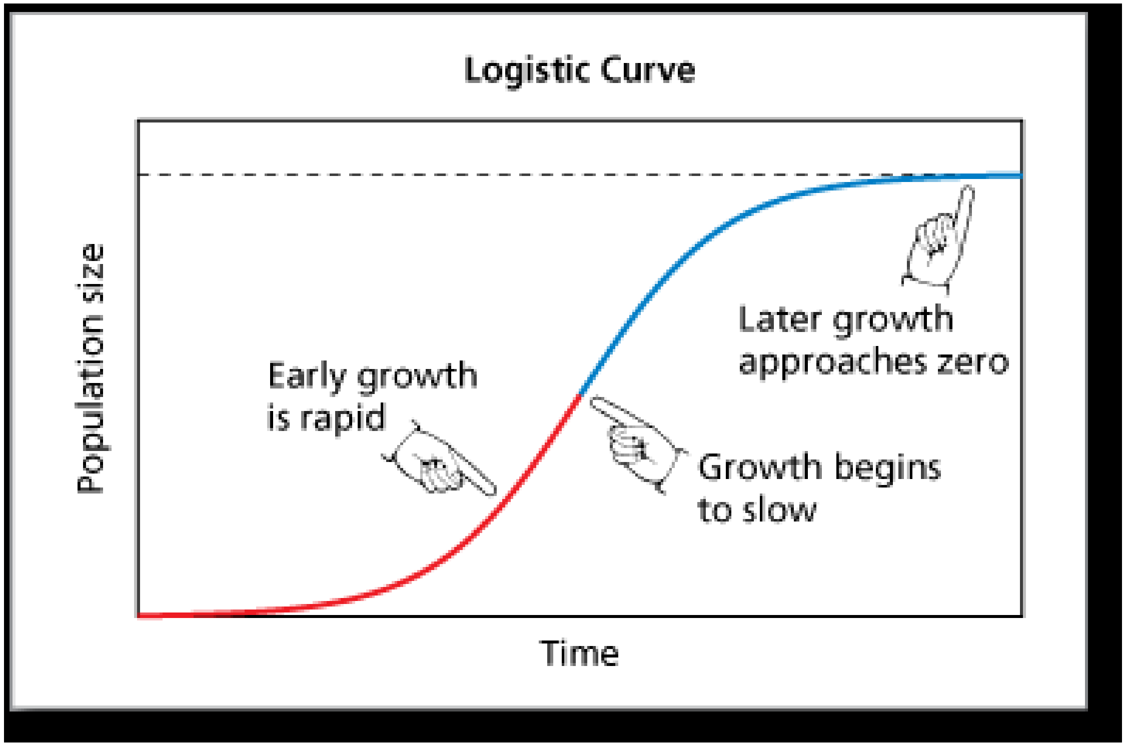
K = carrying capacity

The maximum population size a particular environment can sustain.



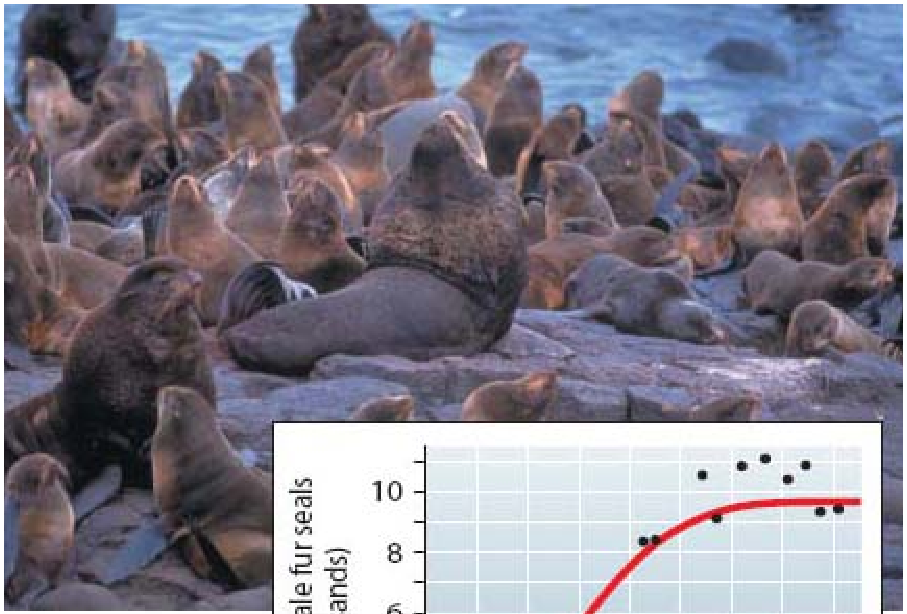
Limiting Factors & the Logistic Growth Model

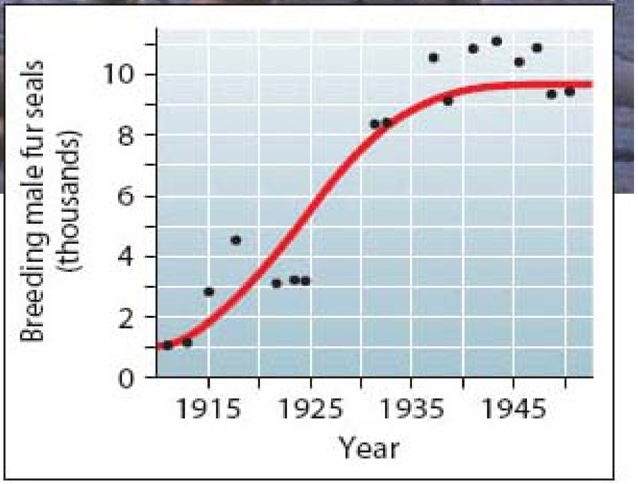
- **In nature, a population that is introduced to a new environment or is rebounding from a catastrophic decline in numbers *may* grow exponentially for a while, but eventually, one or more environmental factors will limit its growth.**
  - **Environmental factors that restrict population growth are called <u>limiting factors</u>.**



Limiting Factors & the Logistic Growth Model

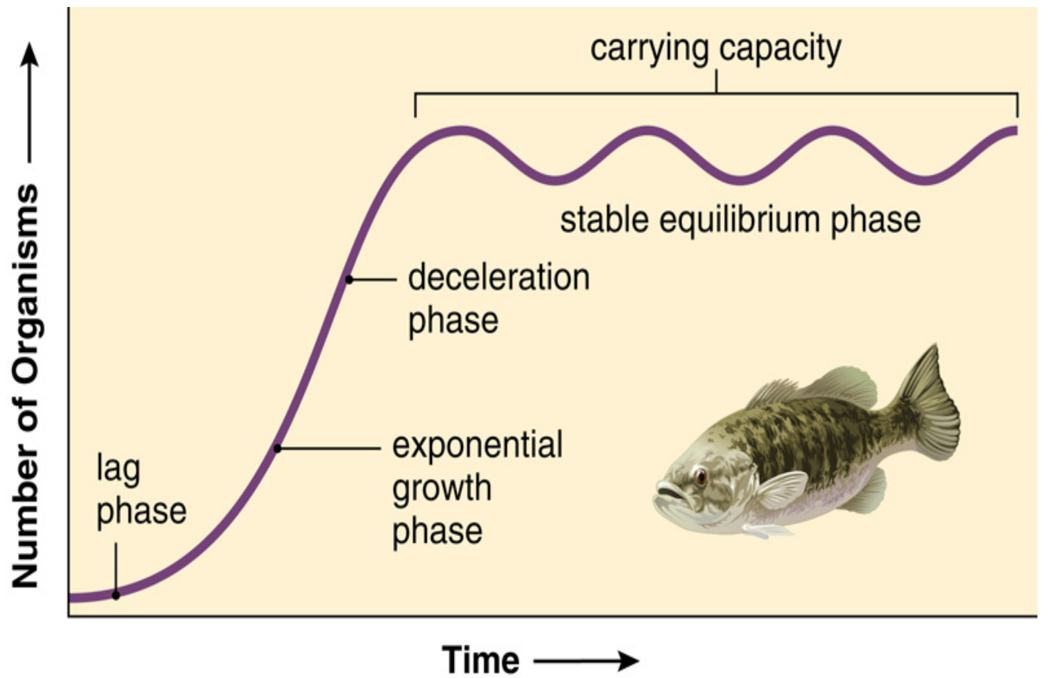
- **You can see the effect of population-limiting factors in this graph, which illustrates the growth of a population of fur seals on St. Paul Island, off the coast of Alaska.**
  - **Before 1925, the seal population on the island remained low because of uncontrolled hunting. After hunting was controlled, the population increased rapidly until about 1935, when it began to level off and started fluctuating around a population size of about 10,000 bull seals.**
    - **At this point, a number of limiting factors, including some hunting and the amount of space suitable for breeding, restricted population growth.**



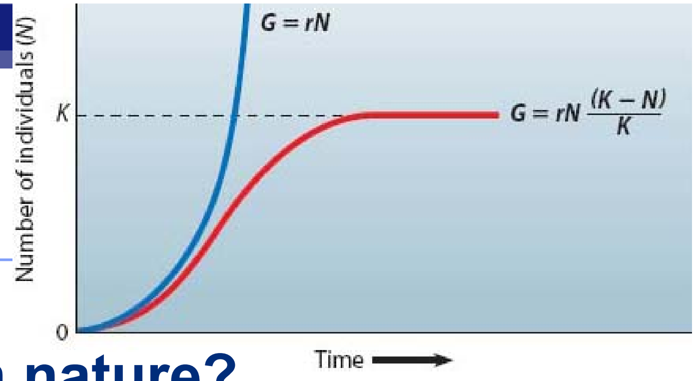


What is the Carrying Capacity Can Change.

- Even in one location, K is not a fixed number.
  - Organisms interact with other organisms in their communities, including predators, parasites, and food sources, that may affect K.
    - Changes in abiotic factors may also increase or decrease carrying capacity.
    - In any case, the concept of carrying capacity expresses an essential fact of nature: Resources are finite!!!
      - K varies with changes in resources



Logistic Growth Model



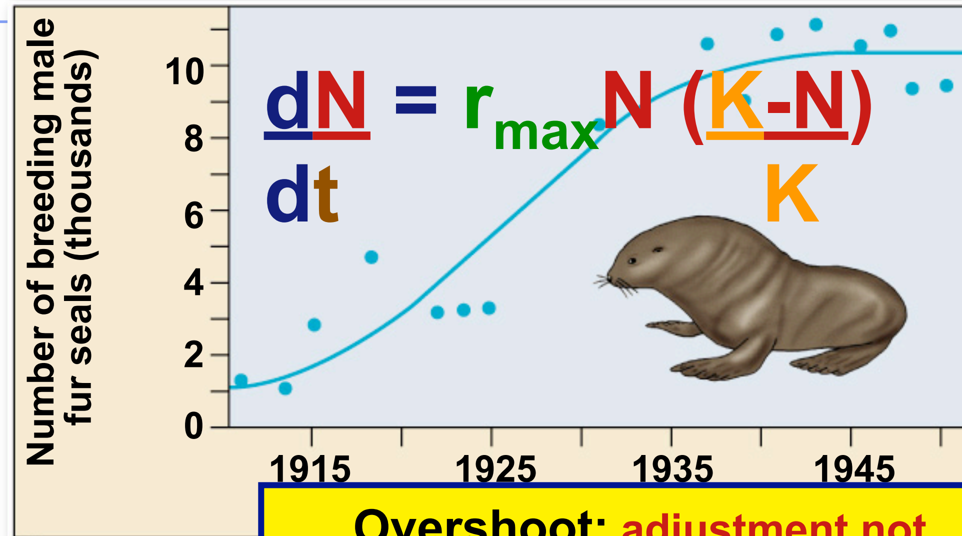
- **What does the logistic growth model suggest to us about real populations in nature?**
  - **The model predicts that a population's growth rate will be small when the population size is either small or large, and highest when the population is at an intermediate level relative to the carrying capacity.**
    - **At a <u>low</u> population level, resources are abundant, and the population is able to grow nearly exponentially.**
      - **the increase is small because N is small.**
    - **In contrast, at a <u>high</u> population level, limiting factors strongly oppose the population's potential to increase.**
      - **There might be less food available per individual or fewer breeding territories, nest sites, or shelters.**
        - **These <u>limiting factors</u> cause the birth rate to decrease, the death rate to increase, or both.**
          - **Eventually, the population stabilizes at the <u>carrying capacity</u> (K), when the birth rate equals the death rate.**
- **K occurs when <u>B = D</u>** *(the population is not changing in size)*

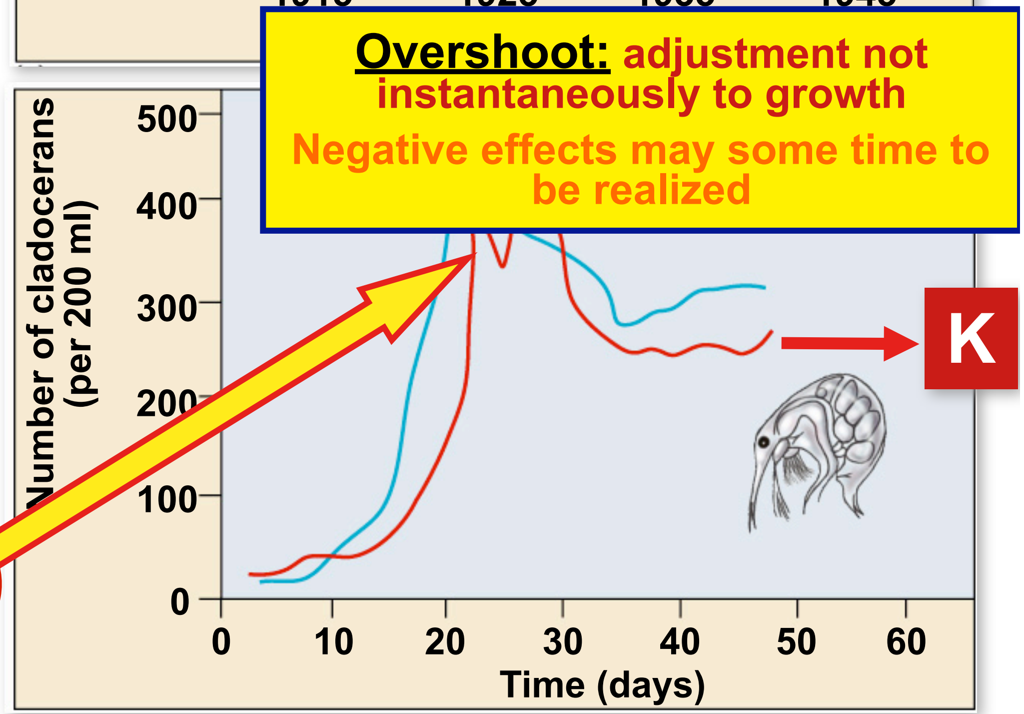
Logistic Population Growth - S sigmoid curve

- K = Maximum population size that environment can support with no degradation of habitat

- New individuals are added most rapidly at intermediate population sizes when you have:
  1. Considerable size of breeding population
  2. Lots of available space & resources (like nutrients/water/ sunlight etc..)

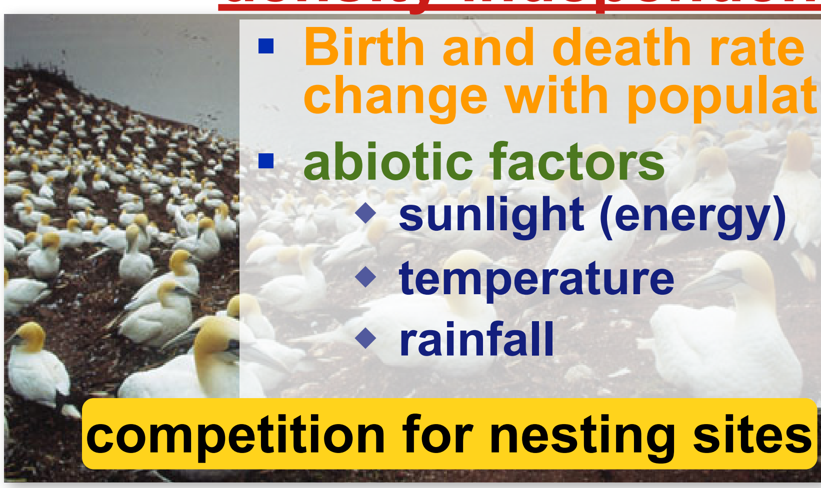
- As N approaches K:
  - Population growth rate slows dramatically as approach K



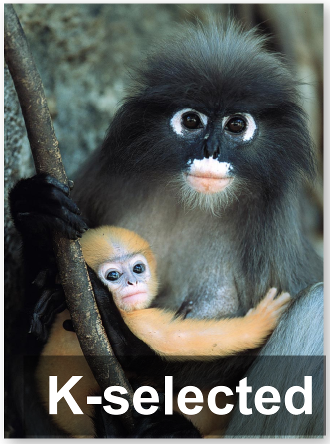


Regulation of population size

- Limiting factors
  - <u>density dependent</u>
  - Death rate that rises as population density rises
  - Biotic factors
    - Competition for resources: food, mates, nesting sites
    - Predators, parasites, pathogens (disease)
    - Accumulation of Toxic Waste
  - <u>density independent</u>
    - Birth and death rate does not change with population density
    - abiotic factors
      - sunlight (energy)
      - temperature
      - rainfall



Reproductive strategies



- **K-selection**
  - Density-Dependent selection
  - Selection for life history traits that are sensitive population density
    - Adaptations favored that enable organisms to survive/reproduce with few resources
    - Competitive ability and efficient use of resources favored
    - late reproduction
    - few offspring
    - invest a lot of energy in raising offspring
      - primates & coconut

Operates in populations near carrying capacity

- **r-selection**
  - Density-independent selection
  - Selection for life history traits that maximize reproductive success in uncrowded environments (low densities)
    - Adaptations that promote rapid reproduction
    - early reproduction
    - Many small offspring
    - little parental care
      - insects & many plants

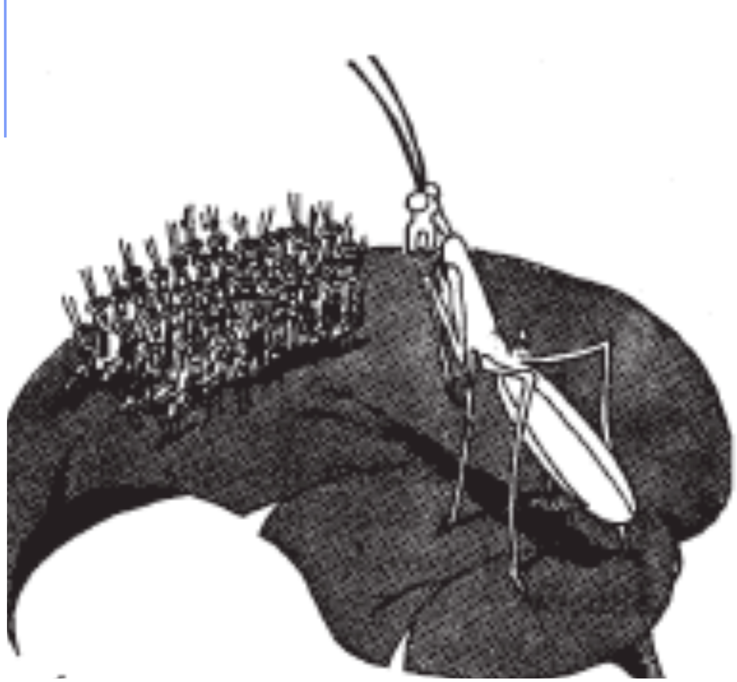
Operates in populations well below carrying capacity
Ex: in disturbed habitats

Trade offs

Number & size of offspring

vs.

Survival of offspring & parent

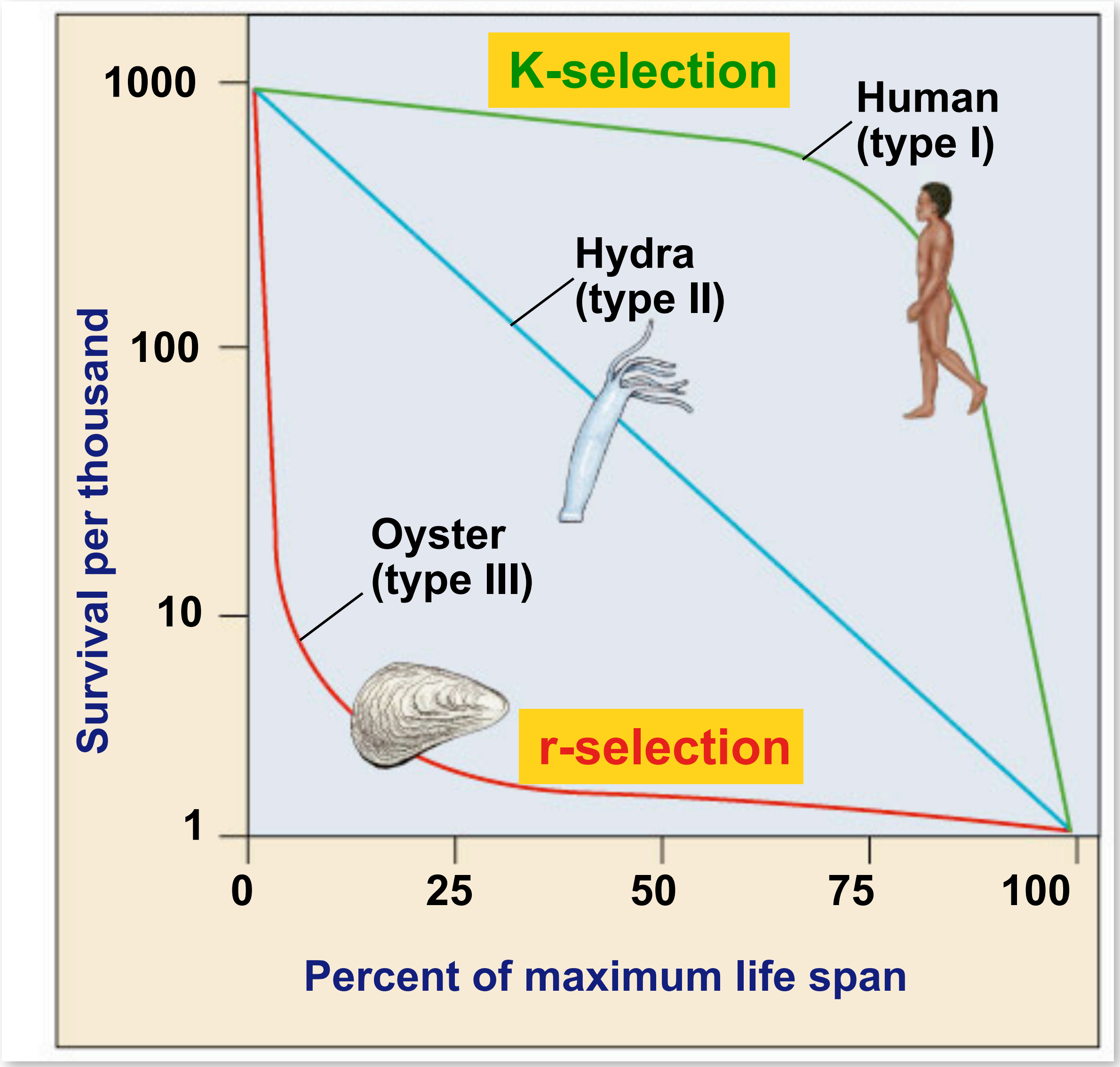


"Of course, long before you mature, most of you will be eaten."

(a) Most weedy plants, such as this dandelion, grow quickly and produce a large number of seeds, ensuring that at least some will grow into plants and eventually produce seeds themselves.

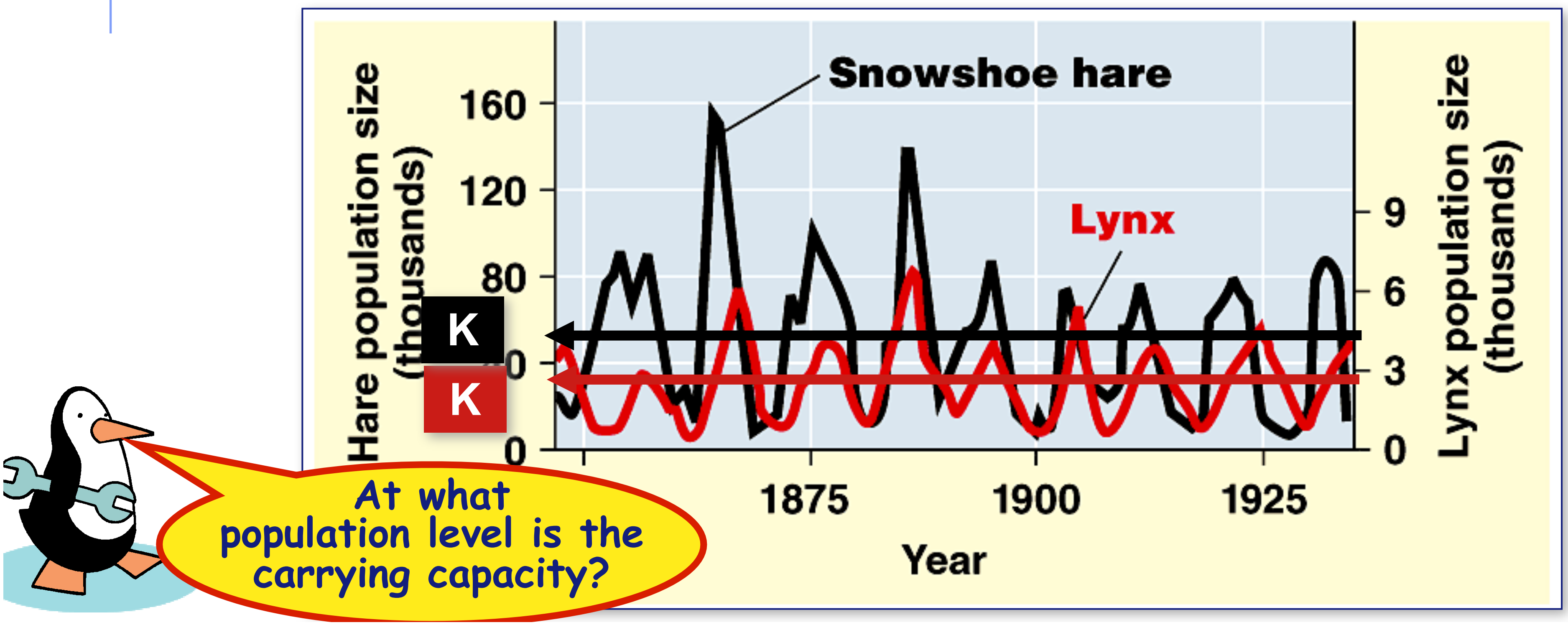
(b) Some plants, such as this coconut palm, produce a moderate number of very large seeds. The large endosperm provides nutrients for the embryo, an adaptation that helps ensure the success of a relatively large fraction of offspring.

Different Life Strategies *(to survive and reproduce)* have evolved based on environmental circumstances, each species correlated to a type of survivorship curve.



Changes in Carrying Capacity over time are caused at times by changes in *prey or predator numbers*

- **Population Cycles Occur**
  - **due to predator – prey interactions**
    - As # of hare increases there is more food for the lynx so lynx # rise as a result.
    - As # of lynx rise, more eat the hare so following lynx population growth, hare #'s drop.
    - As hare #'s drop, there is less food for the lynx, so lynx #'s drop again and the cycle continues.



Human population growth

adding ~83 million/year
>227,000+ per day!

Doubling times

250m → 500m = y (long)

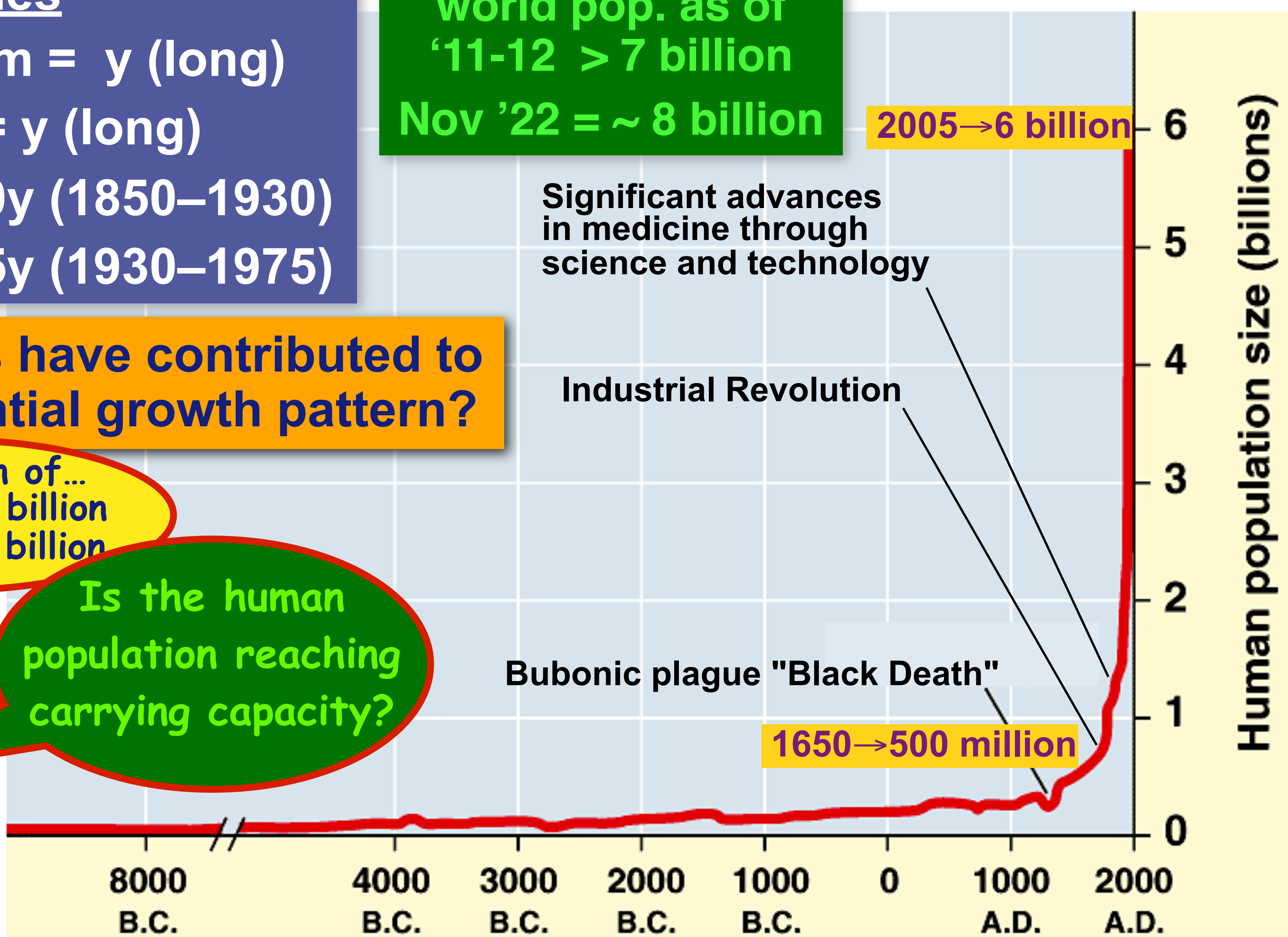
500m → 1b = y (long)

1b → 2b = 80y (1850–1930)

2b → 4b = 75y (1930–1975)

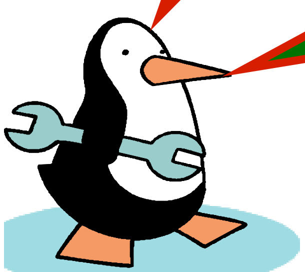
world pop. as of
'11-12 > 7 billion
Nov '22 = ~ 8 billion

What factors have contributed to this exponential growth pattern?



Population of…
China: 1.41 billion
India: 1.39 billion

Is the human population reaching carrying capacity?



Any Questions?