BHARATHIDASAN UNIVERSITY

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Programme: M.Sc., Environmental Science and Sustainable Management

Course Title : **Geospatial data Modelling and Informatics**

Course Code : 21PGCC05

Module-I

Basics of Ecological Models Part 1

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POPULATIONS AND GROWTH MODELS

HOW POPULATIONS GROW

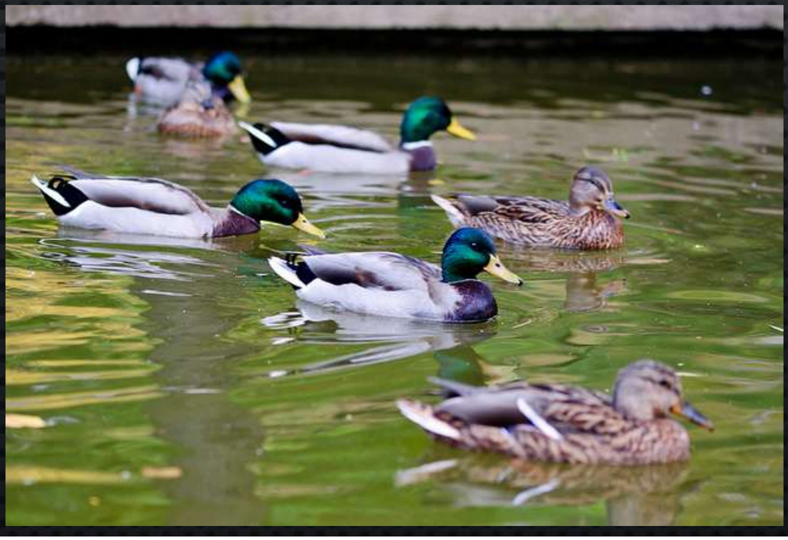
- Characteristics of Populations
  - **Three important characteristics of a population**
    1. **Geographic distribution**
    2. **Density**
    3. **Growth rate**

GEOGRAPHIC DISTRIBUTION

- A POPULATION'S RANGE CAN VARY ENORMOUSLY IN SIZE, DEPENDING ON THE SPECIES.
- BACTERIA IN PUMPKIN VS COD SWIMMING FROM GREENLAND-NORTH CAROLINA

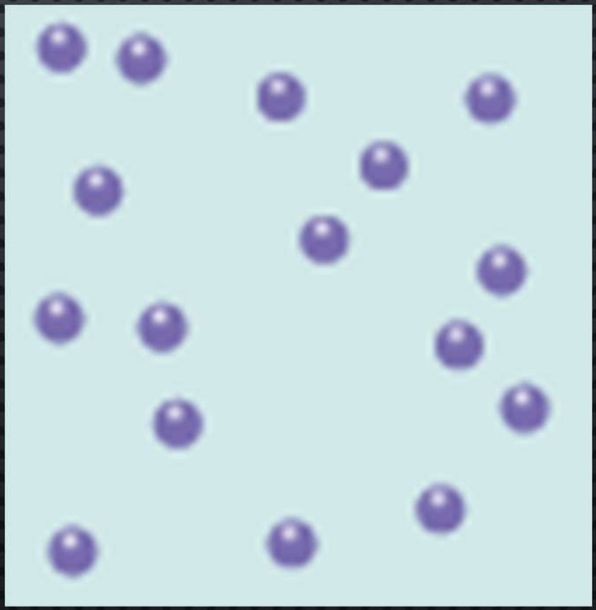
2- POPULATION DENSITY

- **POPULATION DENSITY** IS THE NUMBER OF INDIVIDUALS PER UNIT AREA.
- THE POPULATION OF DUCKS IN A POND MAY HAVE A LOW DENSITY, WHILE FISH IN THE SAME POND HAVE A HIGHER DENSITY



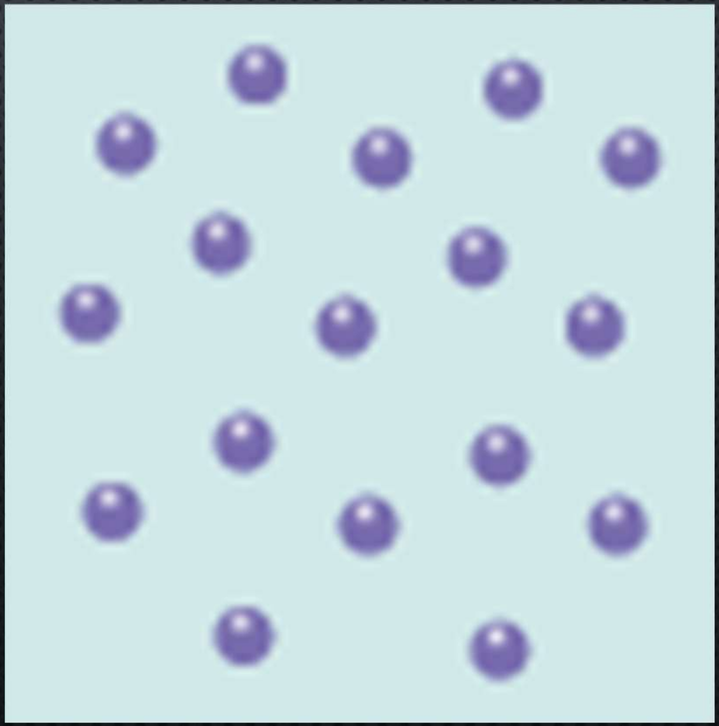
DENSITY AND DISTRIBUTION

- AN EXAMPLE OF A POPULATION THAT SHOWS RANDOM DISTRIBUTION IS THE PURPLE LUPINE.



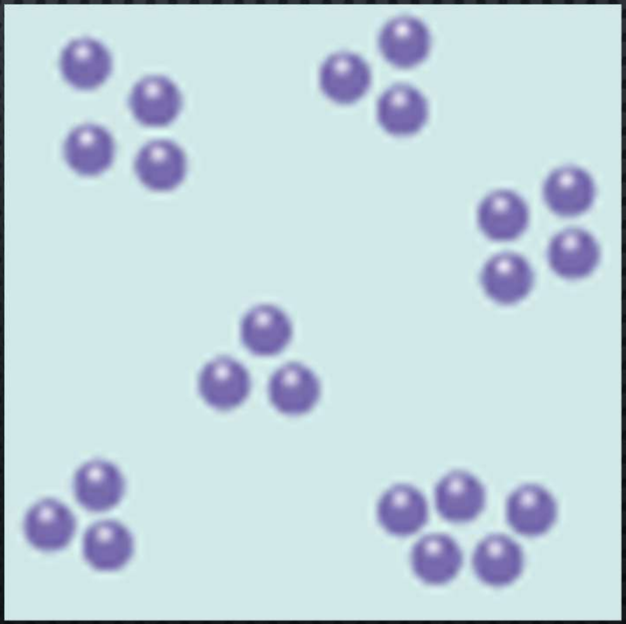
DENSITY AND DISTRIBUTION

- AN EXAMPLE OF A POPULATION THAT SHOWS UNIFORM DISTRIBUTION IS THE KING PENGUIN.



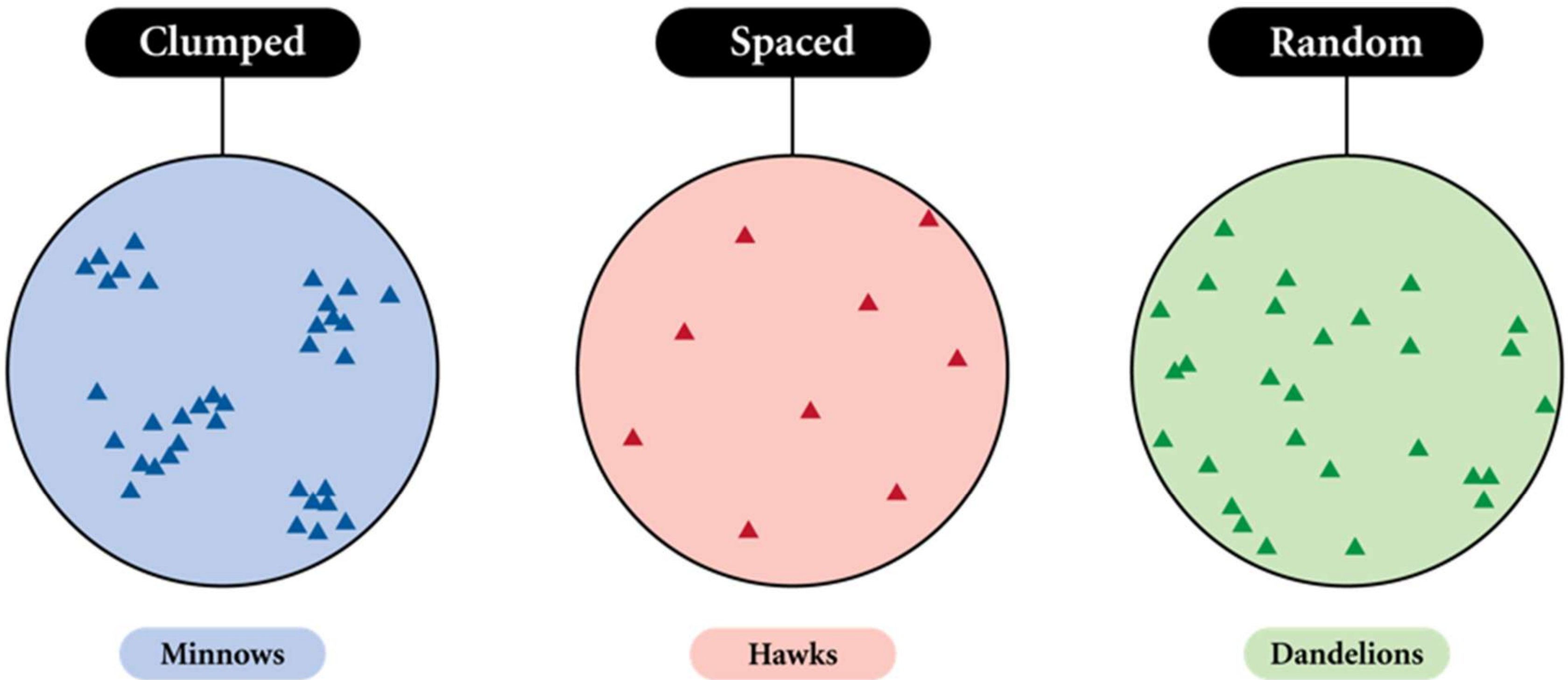
DENSITY AND DISTRIBUTION

- AN EXAMPLE OF A POPULATION THAT SHOWS CLUMPED DISTRIBUTION IS BACTERIA.



Basic Characteristics of Populations

- The suitability of habitats influences the geographic distribution of a species.
- Insights can be gained by studying the spatial distributions of populations within habitats.



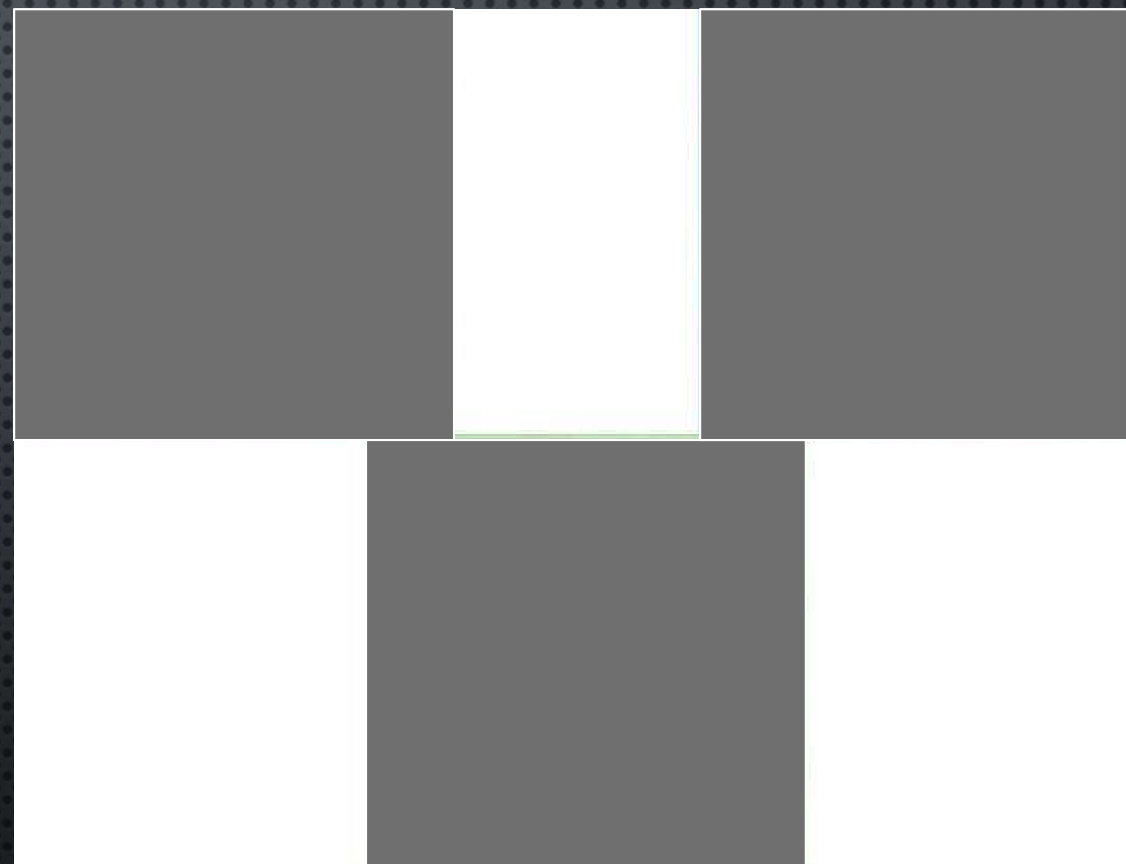
POPULATIONS GROWTH

- THREE FACTORS CAN AFFECT POPULATION SIZE:
  - NUMBER OF BIRTHS
  - THE NUMBER OF DEATHS
  - THE NUMBER OF INDIVIDUALS THAT ENTER OR LEAVE THE POPULATION.

  * SIMPLY PUT, A POPULATION WILL INCREASE OR DECREASE IN SIZE DEPENDING ON HOW MANY INDIVIDUALS ARE ADDED TO IT OR REMOVED FROM IT

BIRTHRATE AND DEATH RATE

- A POPULATION CAN GROW WHEN ITS BIRTHRATE IS HIGHER THAN ITS DEATH RATE.
- IF THE BIRTHRATE EQUALS THE DEATH RATE, THE POPULATION MAY STAY THE SAME SIZE.
- IF THE DEATH RATE IS GREATER THAN THE BIRTHRATE, THE POPULATION IS LIKELY TO SHRINK.

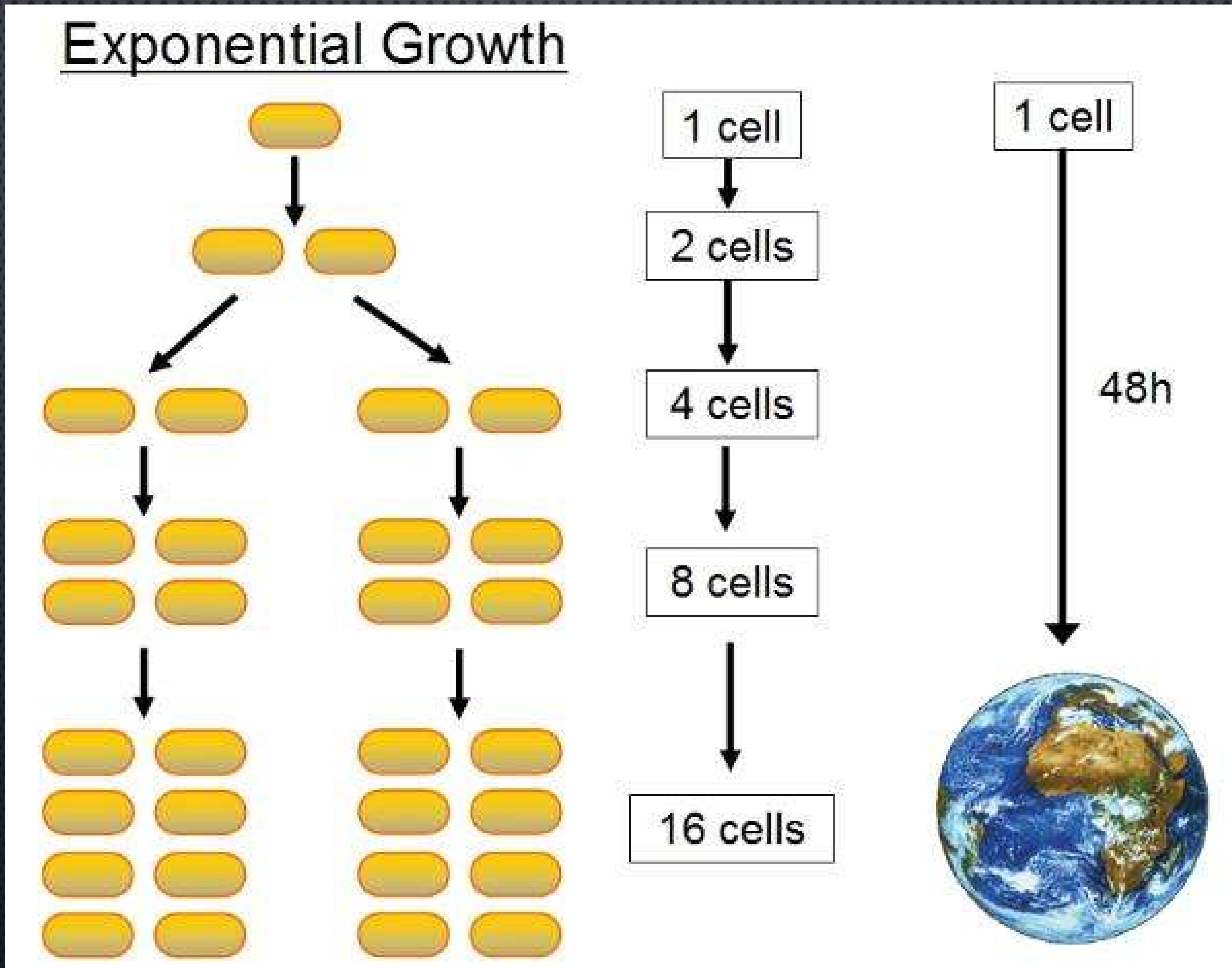


IMMIGRATION & EMMIGRATION

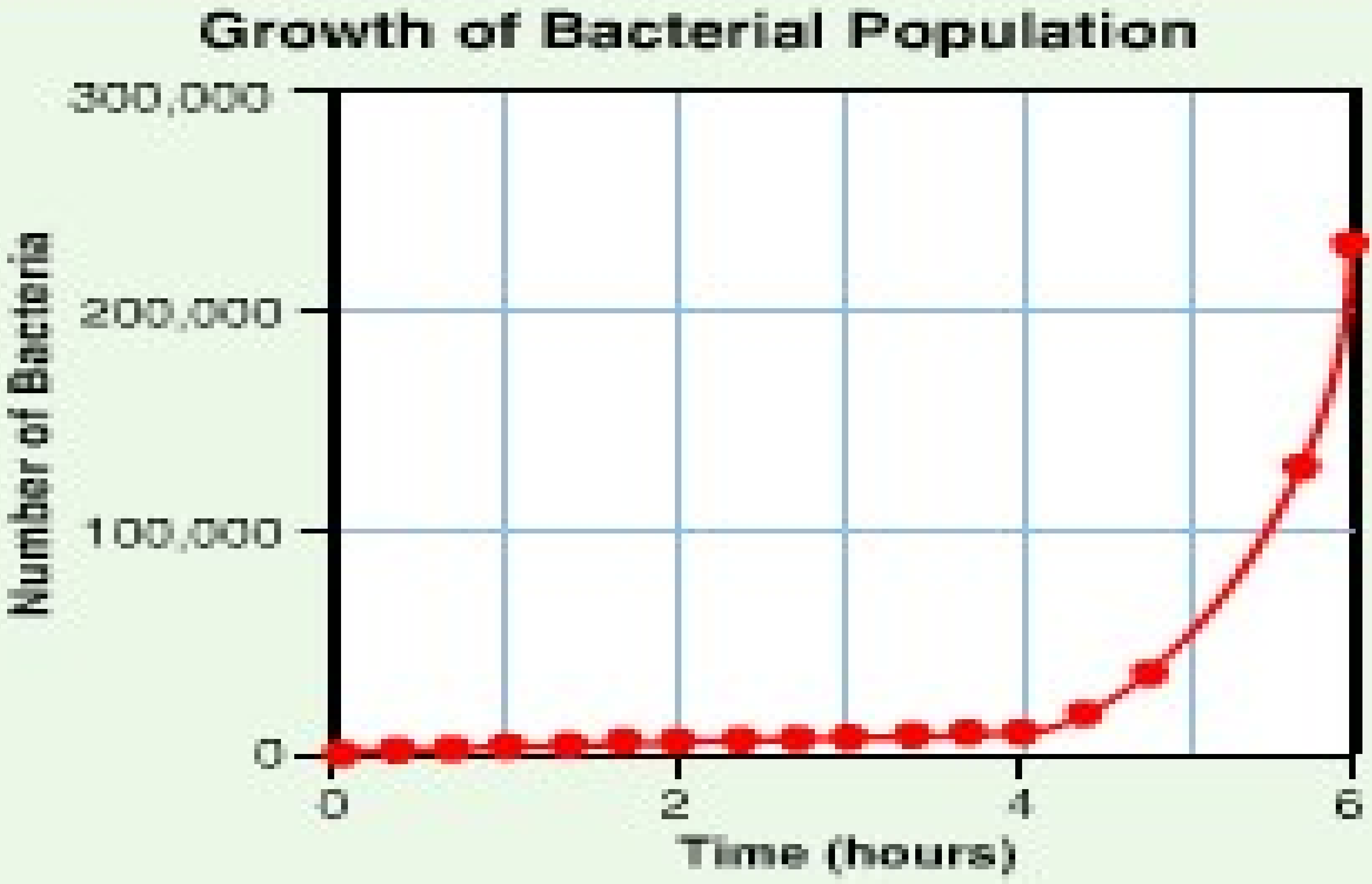
- **Immigration**
  - THE MOVEMENT OF INDIVIDUALS INTO AN AREA, IS ANOTHER FACTOR THAT CAN CAUSE A POPULATION TO GROW.
- **Emigration**
  - THE MOVEMENT OF INDIVIDUALS OUT OF AN AREA, CAN CAUSE A POPULATION TO DECREASE IN SIZE.

EXPONETIAL GROWTH

- **Exponential Growth**
  - If a population has abundant space and food, and is protected from predators and disease, then organisms in that population will multiply and the population size will increase.


Exponential Growth
1 cell
2 cells
4 cells
8 cells
16 cells
1 cell
48h

Exponential Growth



CHECKPOINT

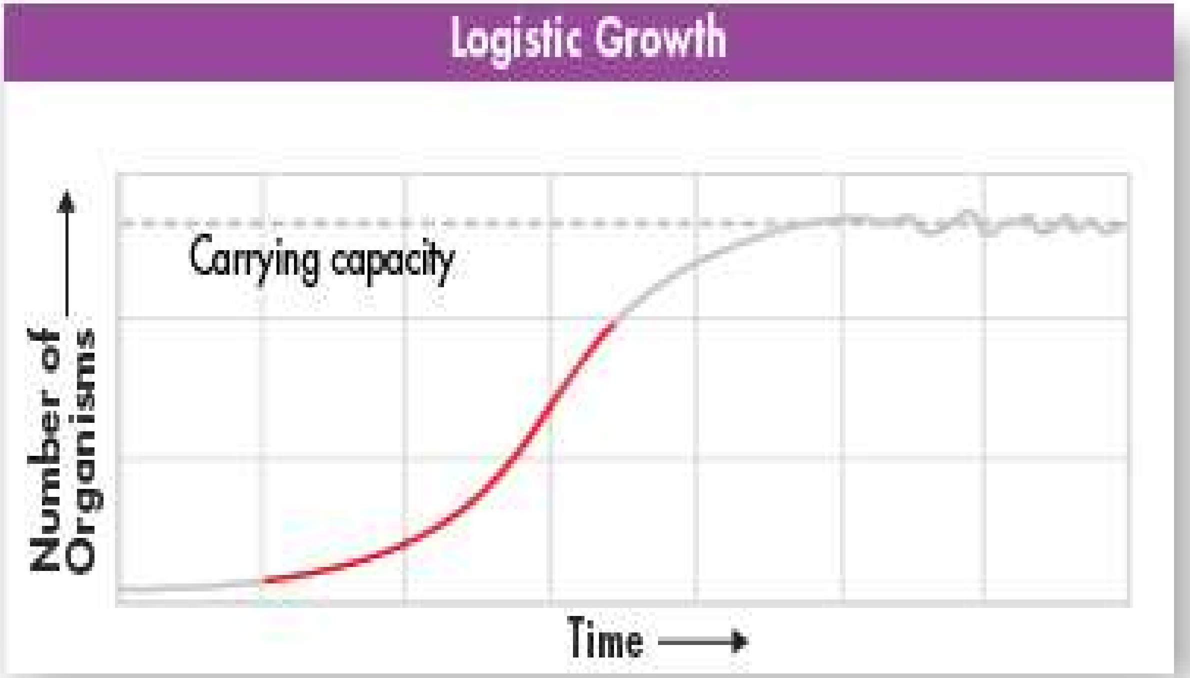
WHICH OF THE FOLLOWING IS NOT A CONDITION FOR A POPULATION TO REACH EXPONENTIAL GROWTH?

- **A.) PRESENCE OF UNLIMITED RESOURCES**
- **B.) ABSENCE OF PREDATION AND DISEASE**
- **C.) MOVEMENT OF INDIVIDUALS OUT OF THE POPULATION**

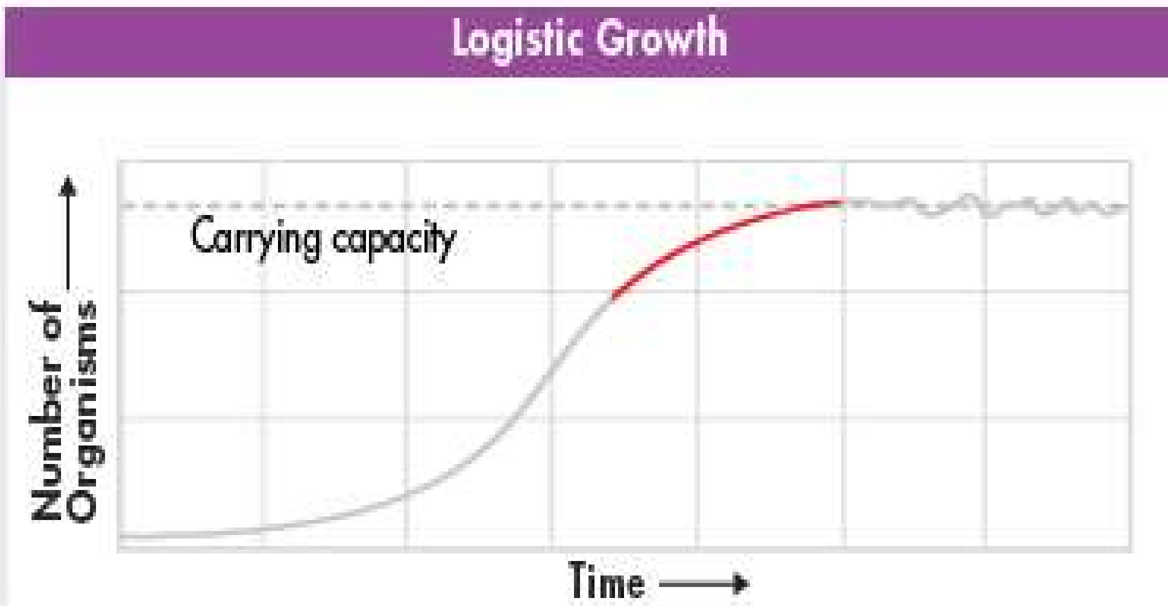
LOGISTIC GROWTH

- **LOGISTIC GROWTH** OCCURS WHEN A POPULATION'S GROWTH SLOWS OR STOPS FOLLOWING A PERIOD OF EXPONENTIAL GROWTH.
- **AS RESOURCES BECOME LESS AVAILABLE, THE GROWTH OF A POPULATION SLOWS OR STOPS.** THE GENERAL, S-SHAPED CURVE OF THIS GROWTH PATTERN, CALLED LOGISTIC GROWTH

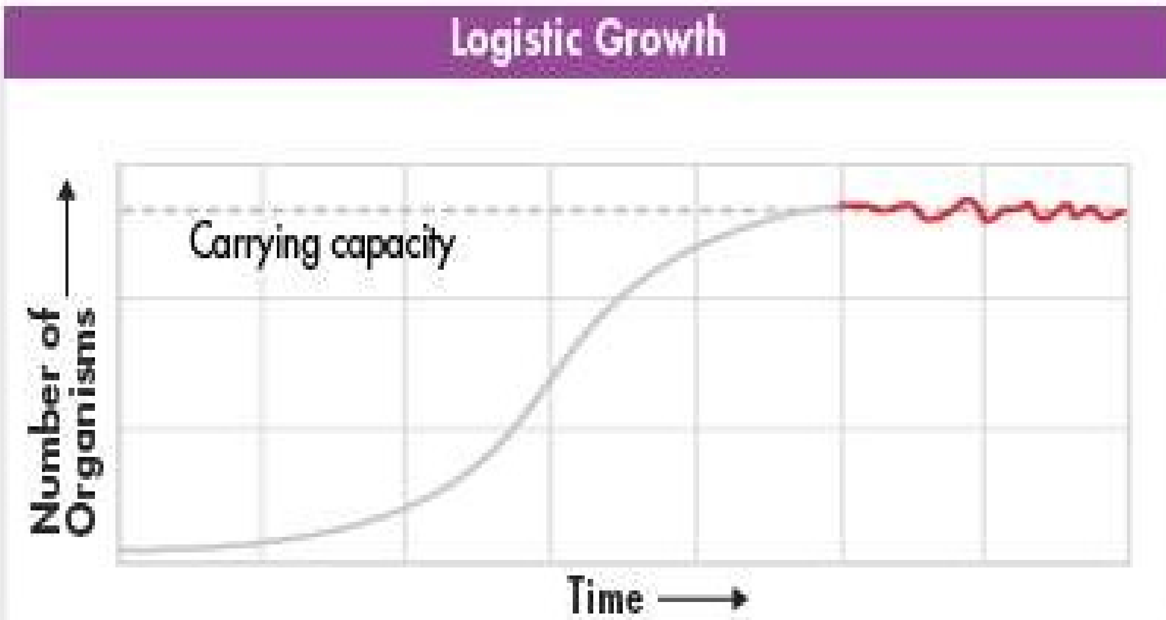
PHASE 1: EXPONENTIAL GROWTH



PHASE 2: GROWTH SLOWS DOWN.



PHASE 3: GROWTH STOPS.



TYPES OF POPULATION GROWTH CURVES

There are mainly two types of population growth curves-

1. Exponential growth curve(J-shaped)

&

2. Sigmoid growth curve(S-shaped)

EXPONENTIAL GROWTH CURVE

- In this type of growth form, the population grows exponentially, and after attaining the peak value the population may abruptly crash.
- This increase in population is continued till large amount of food materials exist in the habitat.
- After sometime, due to increase in population size the food supply in the habitat becomes limited which ultimately results in decrease in population size.

Continue….

- For example, many insect populations show explosive increase in numbers during the rainy season, followed by their disappearance at the end of the season.
- The following equation exhibits J-shaped growth:

$$dN/dt = rN$$

where,

dN/dt represents rate of change in population.

r=biotic potential

N= population size

Continue.......

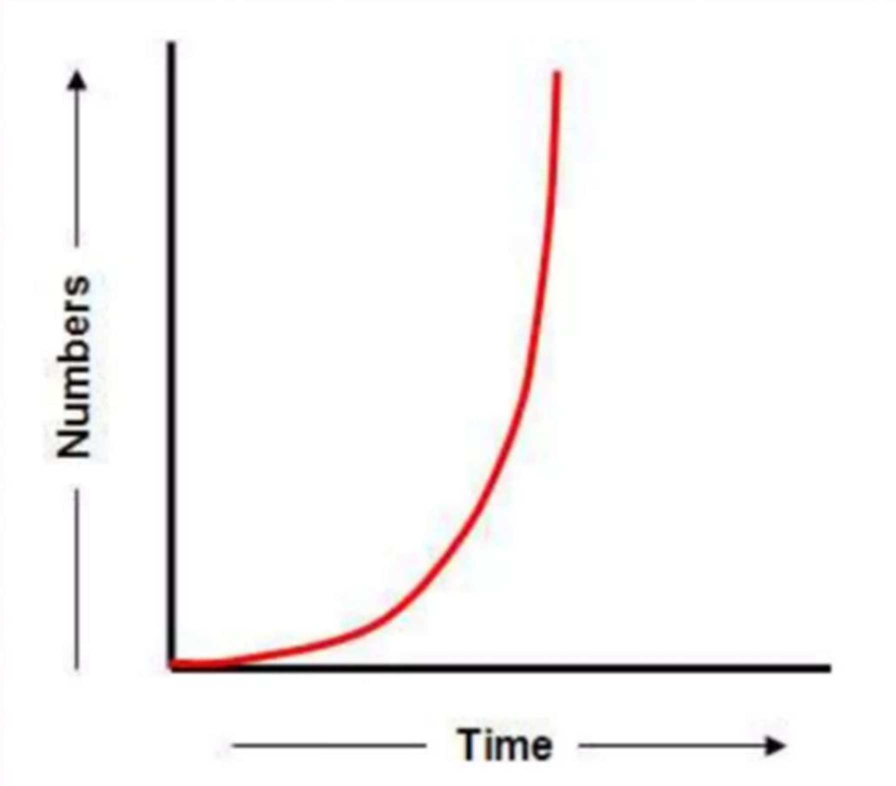


Figure: J-shaped growth curve

SIGMOID GROWTH CURVE

- The sigmoid growth curve is also known as Logistics growth curve which is S-shaped.
- When a few organisms are introduced in an area, the population increase is very slow in the beginning i,e., the positive acceleration phase or lag phase.
- In the middle phase the population increase becomes very rapid which is known as logarithmic phase.
- Finally in the last phase the population increase is slowed down i,e. negative acceleration phase.

Continue....

- The level beyond which no major increase can occur is referred to as saturation level or carrying capacity which is denoted by K.
- In the last phase the new organisms are almost equal to the number of dying individuals and thus there is no more increase in the population size.

Continue....

- The J-shaped (sigmoid) growth form is represented by the following equation:

$$dN/dt = rN(K-N/K)$$
$$=rN(1-N/K)$$

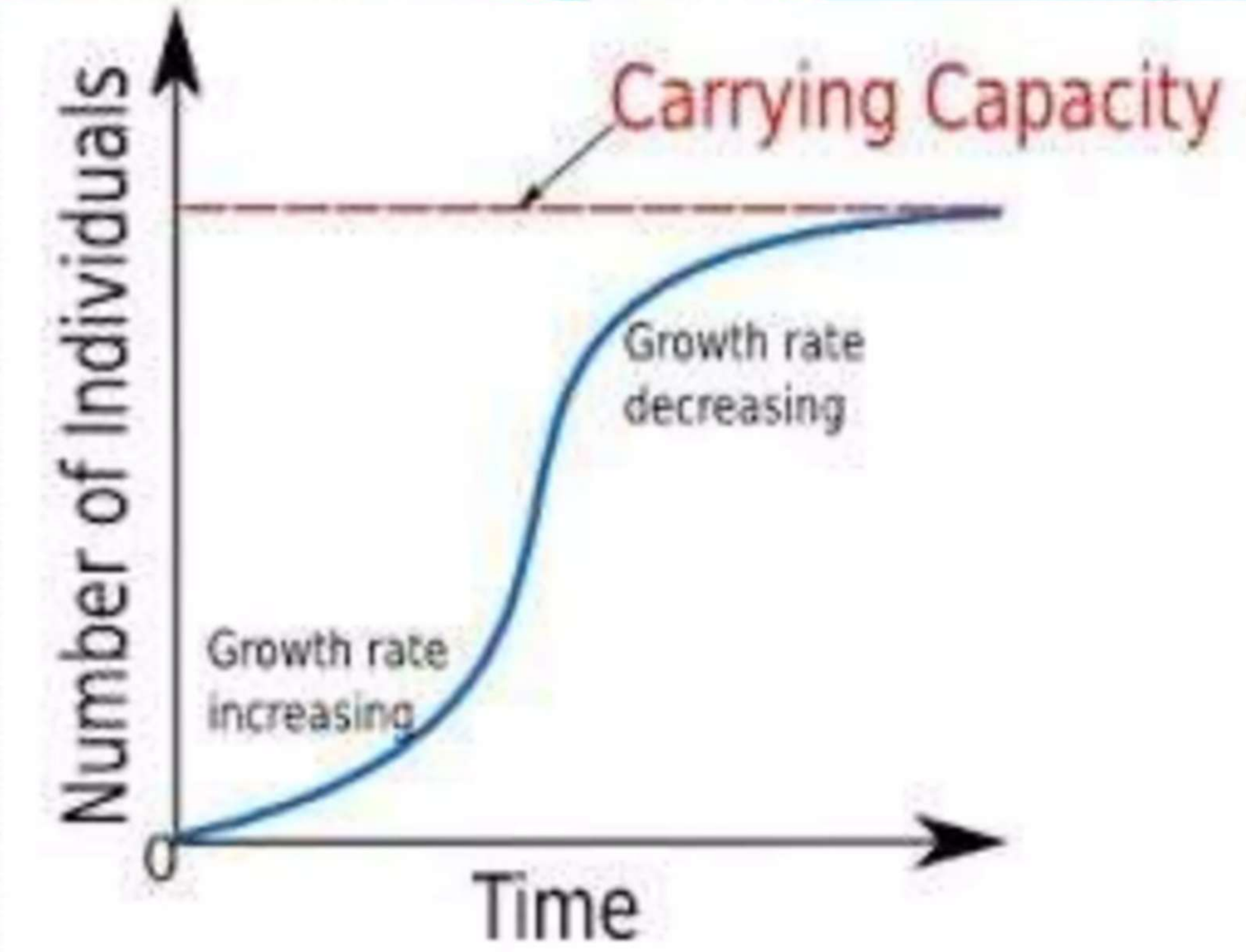
Here,

dN/dt is the rate of change in population size.

r= biotic potential

N= population size

(K-N/K) is for environmental resistance.



S-shaped growth curve

CARRYING CAPACITY?

- The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely , given the food , habitat , water and other necessities available in the environment.

- In population ecology, the carrying capacity is defined as the environment's maximal load.

- Carrying capacity was originally used to determine the number of animals that could graze on a segment of land without destroying it. Later the idea has been expanded to more complex populations.

CARRYING CAPACITY

- THE NUMBER OR THE LARGEST NUMBER OF INDIVIDUALS THAT A GIVEN ENVIRONMENT CAN SUPPORT.

POPULATION ECOLOGY

Population Growth

1. The exponential model of population growth describes an idealized population in an unlimited environment
2. The logistic model of population growth incorporates the concept of carrying capacity

1. The exponential model of population describes an idealized population in an unlimited environment

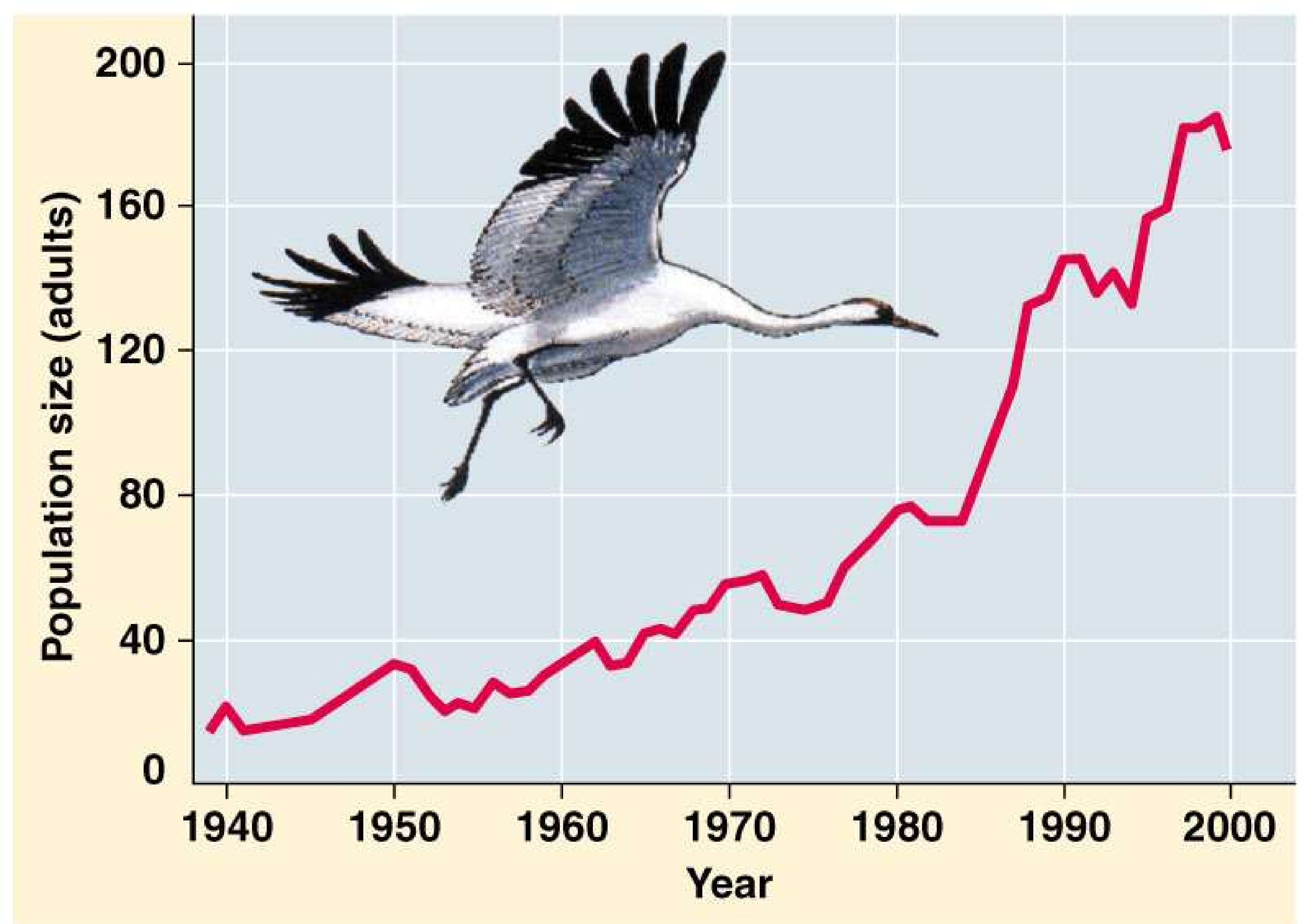
- We define a change in population size based on the following verbal equation.

Change in population = Births during – Deaths during

size during time interval time interval time interval

- Using mathematical notation we can express this relationship as follows:
  - If *N* represents population size, and *t* represents time, then ΔN is the change is population size and Δt represents the change in time, then:
    - $\Delta N / \Delta t = B - D$
    - Where *B* is the number of births and *D* is the number of deaths

- We can simplify the equation and use *r* to represent the difference in per capita birth and death rates.
  - $\Delta N/\Delta t = rN$ or $dN/dt = rN$
- If $B = D$ then there is **zero population growth (ZPG)**.
- Under ideal conditions, a population grows rapidly.
  - **Exponential population growth** is said to be happening
  - Under these conditions, we may assume the maximum growth rate for the population (r_{max}) to give us the following exponential growth
  - $dN/dt = r_{max}N$



Population size (adults)
0
40
80
120
160
200
1940
1950
1960
1970
1980
1990
2000
Year

Fig. 52.9

2. THE LOGISTIC MODEL OF POPULATION GROWTH INCORPORATES THE CONCEPT OF CARRYING CAPACITY

- Typically, unlimited resources are rare.
  - Population growth is therefore regulated by **carrying capacity** (K), which is the maximum stable population size a particular environment can support.

- The logistic growth equation
  - We can modify our model of population growth to incorporate changes in growth rate as population size reaches a carrying capacity.
  - The **logistic population growth** model incorporates the effect of population density on the rate of increase.

- Mathematically, we start with the equation for exponential growth, creating an expression that reduces the rate of increase as *N* increases

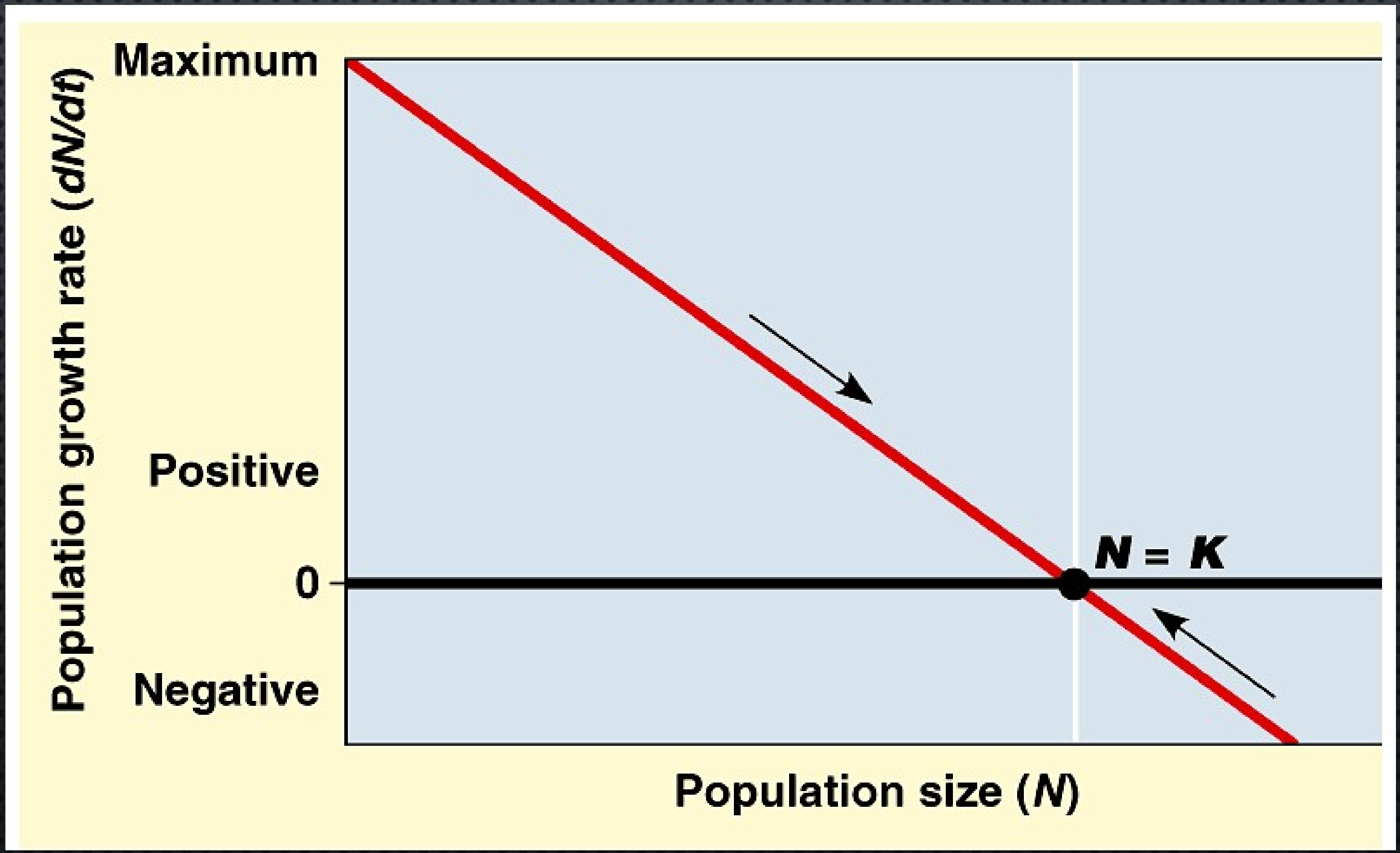


Fig. 52.10

Table 52.3 A Hypothetical Example of Logistic Population Growth, Where $K = 1,000$ and $r_{max} = 0.05$ per Individual per Year

Population Size (N)	Intrinsic Rate of Increase (r_{max})	$\left(\frac{K-N}{K}\right)$	Rate of Population Increase (dN/dt)	ΔN^*
20	0.05	0.98	0.049	+1
100	0.05	0.90	0.045	+5
250	0.05	0.75	0.038	+9
500	0.05	0.50	0.025	+13
750	0.05	0.25	0.013	+9
1,000	0.05	0.00	0.000	0

*ΔN is rounded to the nearest whole number.

Table 52.3

- $dN/dt = r_{max}N((K-N)/K)$
- The graph of this equation shows an S-shaped curve.

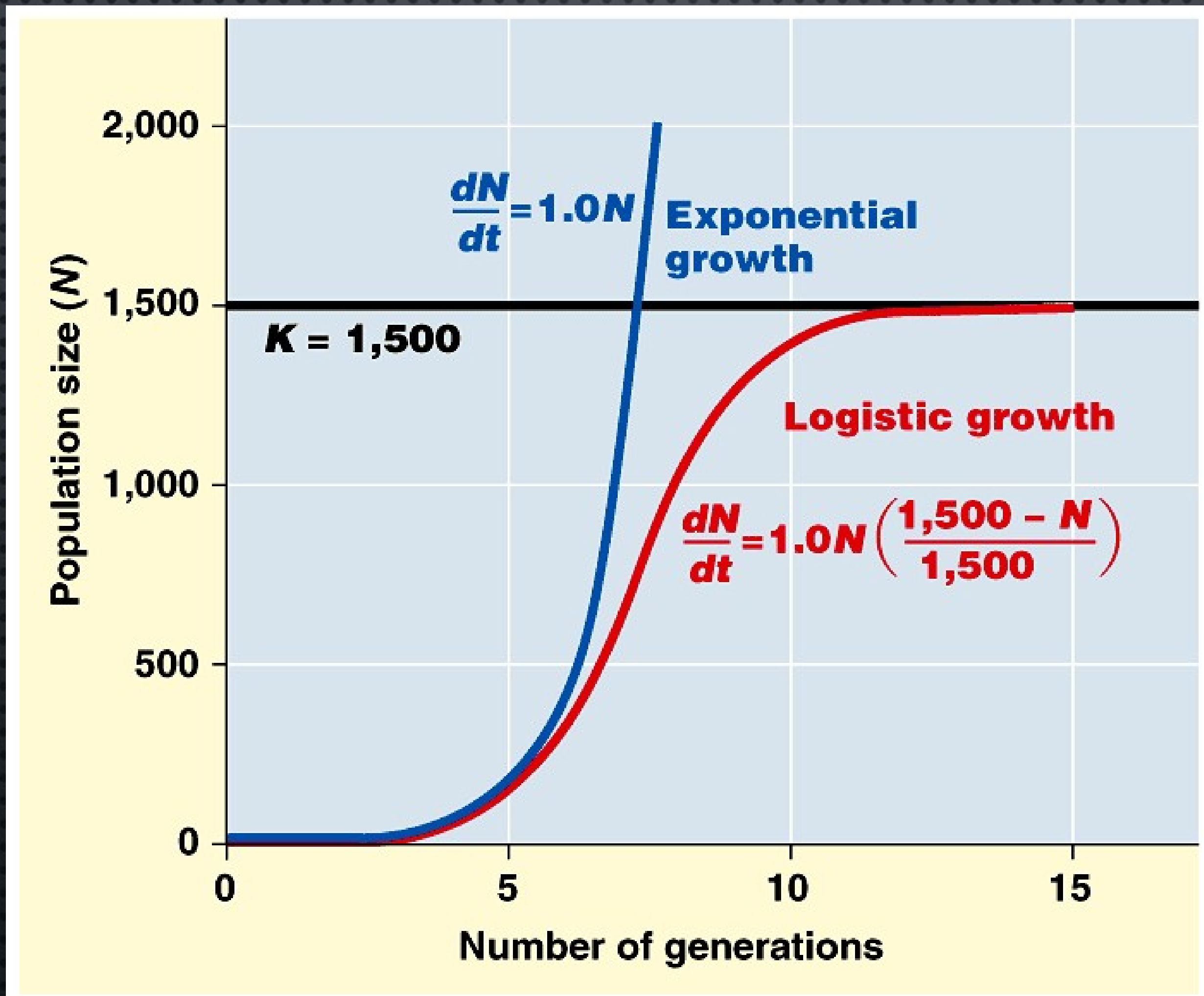
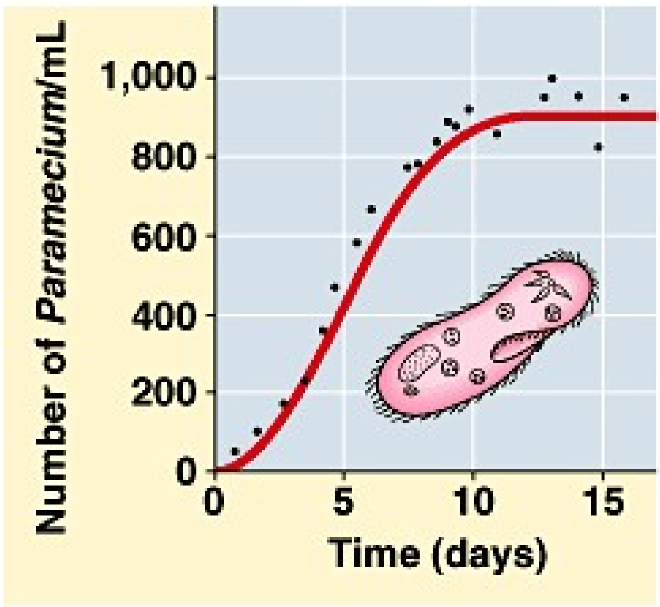
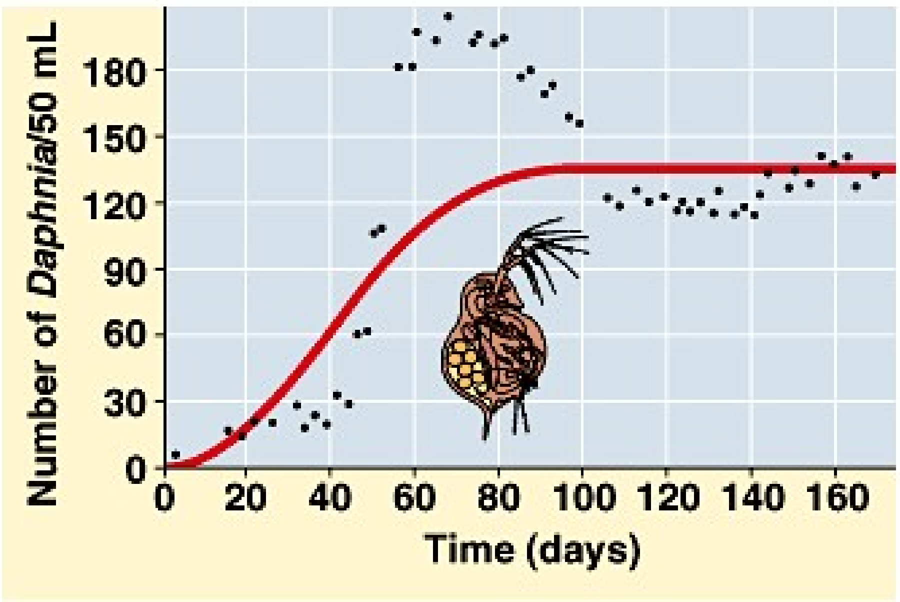


Fig. 52.11

- How well does the logistic model fit the growth of real populations?
    - The growth of laboratory populations of some animals fits the S-shaped curves fairly well.



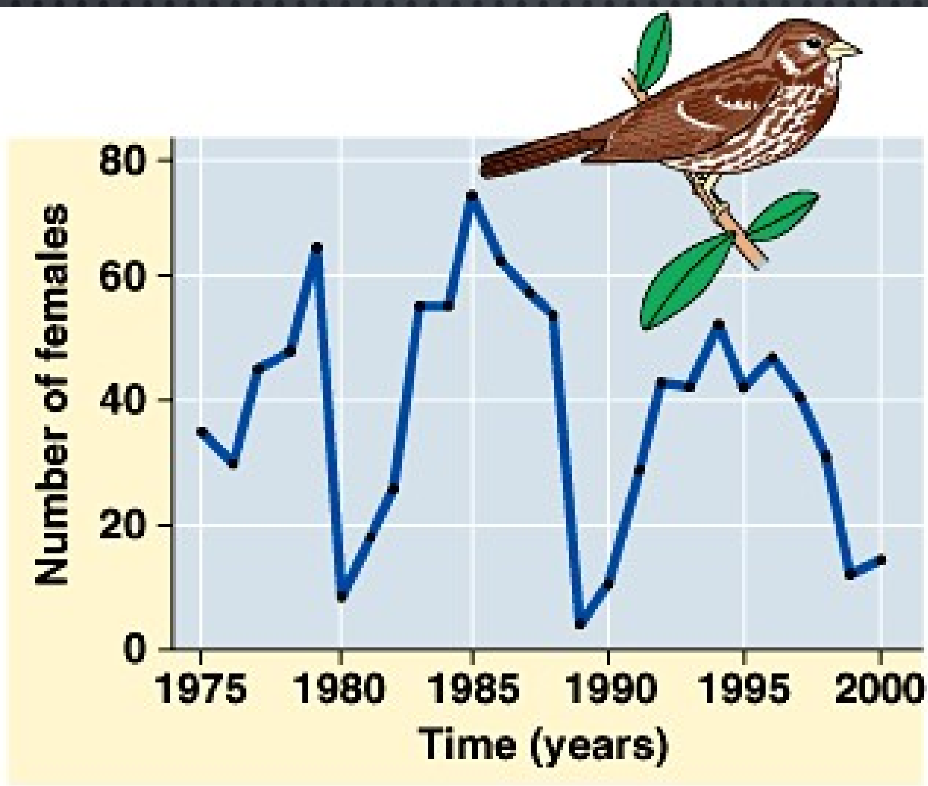
(a) A *Paramecium* population in the lab



(b) A *Daphnia* population in the lab

Fig. 52.12a, b

- Some of the assumptions built into the logistic model do not apply to all populations.
  - It is a model which provides a basis from which we can compare real populations.



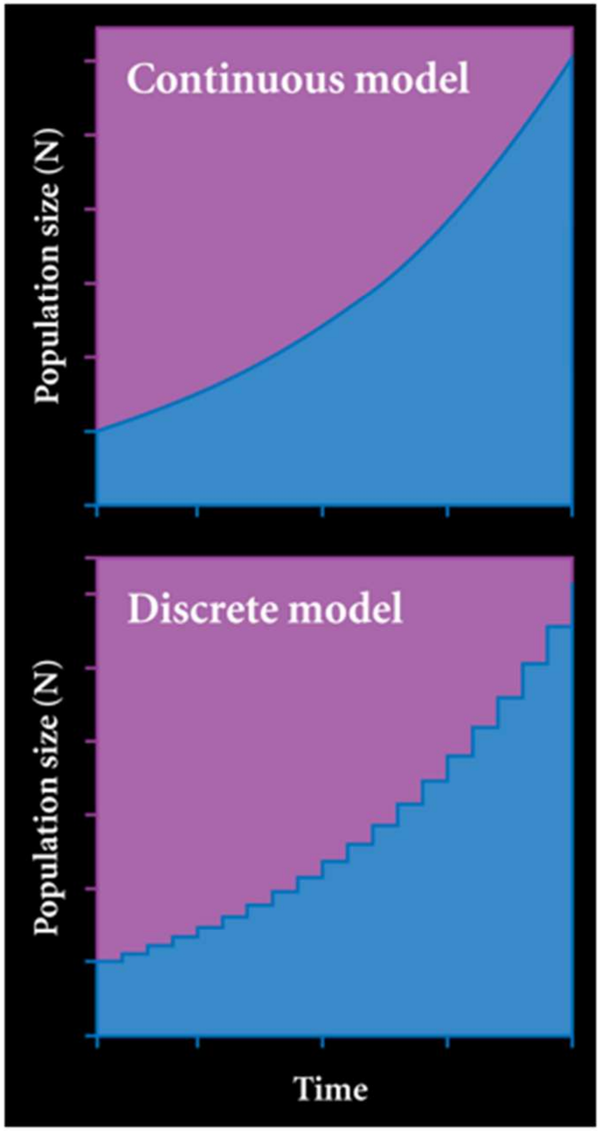
(c) A song sparrow population in its natural habitat

.12c

- The logistic population growth model and life histories.
  - This model predicts different growth rates for different populations, relative to carrying capacity.
    - Resource availability depends on the situation.
    - The life history traits that natural selection favors may vary with population density and environmental conditions.
    - In ***K*-selection**, organisms live and reproduce around *K*, and are sensitive to population density.
    - In ***r*-selection**, organisms exhibit high rates of reproduction and occur in variable environments in which population densities fluctuate well below *K*.

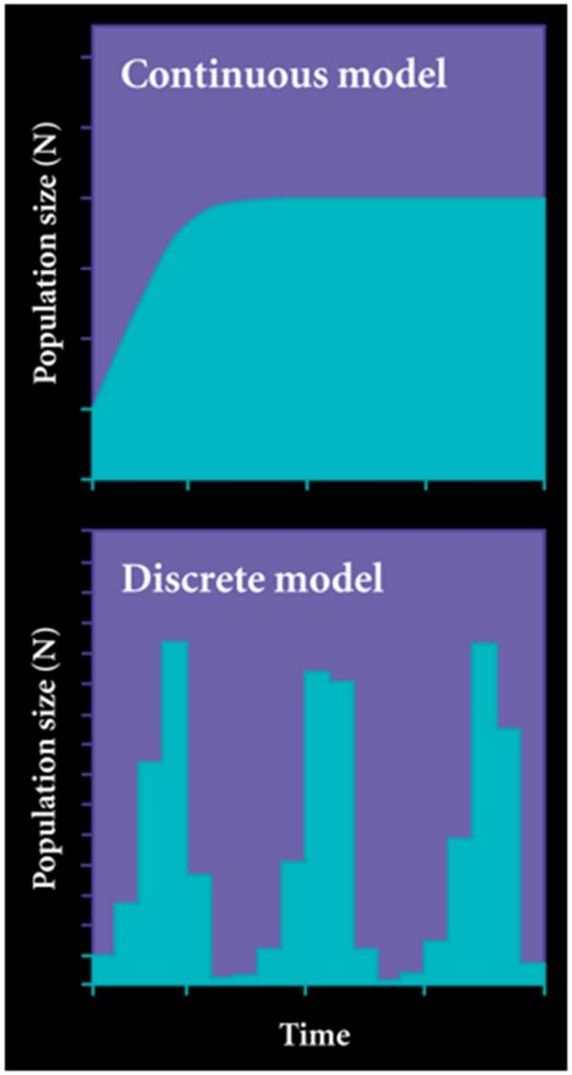
Density-Independent Population Growth

- Simple models describe how idealized populations would grow in an infinite environment.
- In these models, populations increase to infinity or decrease to zero.
- Continuous Model
  - Reproduction occurs in the population at all times.
- Discrete Model
  - Populations reproduce only at certain times.



Density-Dependent Population Growth

- In density dependent population growth, the per capita growth rate decreases as the population approaches a carrying capacity.
- When population growth rate depends on current population size, the population smoothly approaches carrying capacity.
- When there is a delay such that population growth depends on past population sizes, the population may cycle or have chaotic dynamics.

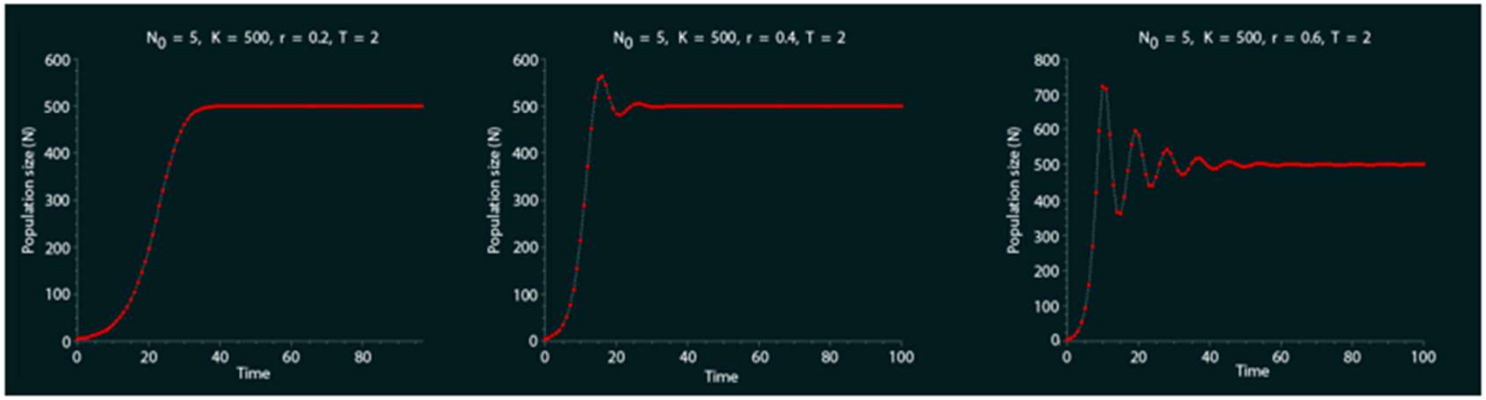


Density-Dependent and Density-Independent Effects on Populations

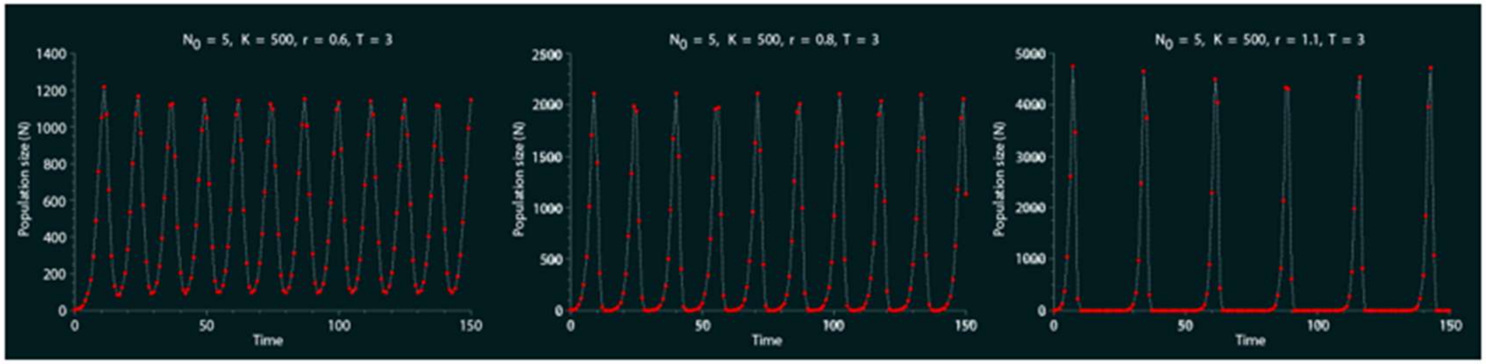
- In many habitats, the forces that limit population sizes are independent of population density. For example, extreme weather events may decrease populations.
- For most species, density-dependent factors limit birth rates or increase death rates at least some of the time. This type of population determination often is referred to as “regulation.”
- Disease outbreaks and starvation are two factors that may increase with population density.

Dynamics of Lagged Logistic Growth Models

- As growth rate increases, populations overshoot carrying capacity (K).



- Further increases cause the population to cycle.

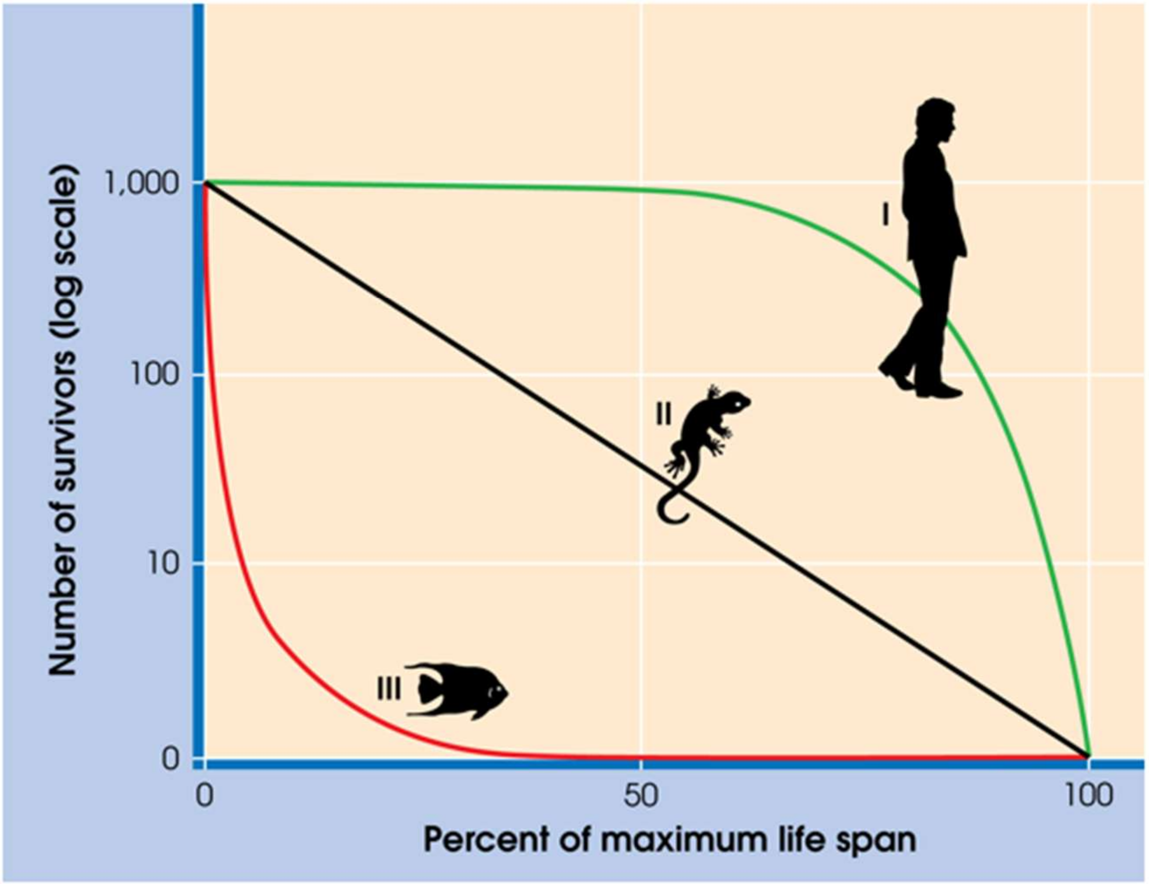


Human Population Growth

- Human population growth does not currently show density effects that typically characterize natural populations.
- In natural populations, per capita population growth rate decreases with population size, whereas global human population growth rate has a positive relationship.
- Human population growth rate has been growing more than exponentially.
- Limited resources eventually will cause human population growth to slow, but global human carrying capacity is not known.

r-selected Reproductive Strategy

- r-selected Species:
  - have high reproductive rates
  - tend to occur in unpredictable environments
  - typically have type III survivorship curves



K-selected Reproductive Strategy

- K-selected Species:
  - occur near carrying capacity
  - experience effects of population density
  - have low reproductive rates, high parental care
  - have type I survivorship curves.