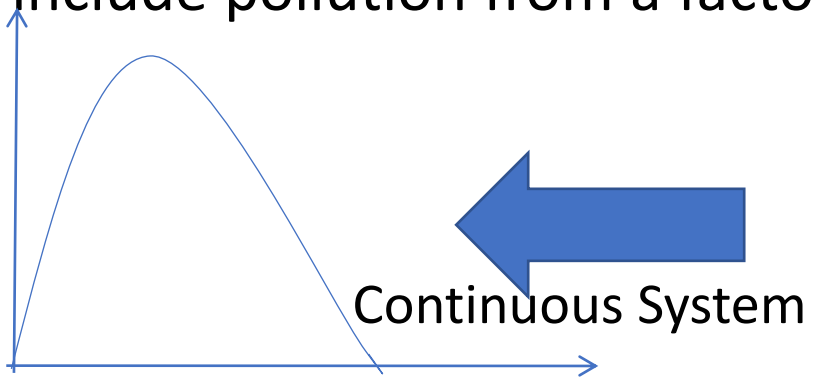
CONTINUOUS SYSTEM

- A Continuous System is whose inputs and outputs are capable of changing at any instance of time.
- In continuous models, time passes linearly and the processes vary directly with time. The inputs of the continuous system may vary continuously by infinitely small time intervals and the system responds to these inputs with continuous output.
- Examples of continuous-system situations include pollution from a factory and the flow of fluid in a pipe.



CONTINUOUS SIMULATION MODEL

- Continuous simulation technique is generally applied on continuous model. Continuous simulation concerns the modeling over time of a system by a representation in which the state variables change continuously with respect to time.
- Typically, continuous simulation models involve differential equations that give relationships for the rates of change of the state variables with time. If the differential equations are particularly simple, they can be solved analytically to give the values of the state variables for all values of time as a function of the values of the state variables at time 0.
- For most continuous modes analytic solutions are not possible. Numerical-analysis techniques are used to integrate the differential equations numerically, given specific values for the state variables at time 0.

System Dynamics

- *System dynamics* is a type of *continuous* simulation that is used for designing and improving policies or strategies in business, government, and the military.
- System dynamics models look at systems at a more aggregate level and are used to make more strategic decisions than most DES models.

Key Components of a System Dynamics Model

- A *stock* is an accumulation of a “resource.” Examples are a population of people or animals, an inventory of a product, or the level of oil in a reserve (continuous variable). Stocks are denoted by rectangles (or containers) in a *stock and flow Diagram*

- A *flow* is a stream of a resource into or out of a stock. Flows are denoted by thick, double-line arrows (or pipes) with a superimposed butterfly valve that controls the *rate* of flow through the pipe.

- An *information link* brings information from a stock (or a variable) to the valve of a flow, and it is typically denoted by a thin curved arrow.

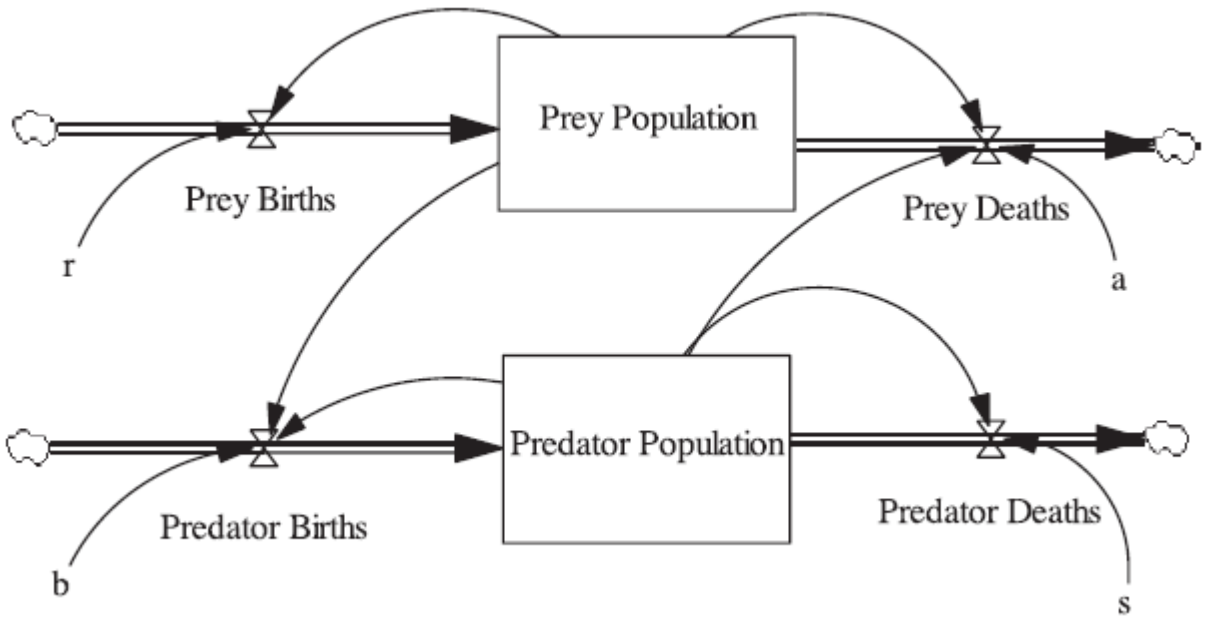


Figure: **Stock and flow diagram for the continuous predator-prey model**.

Predator-Pray Example

- Consider a system dynamics model of what might be called the *classical* predator-prey system, which is formulated using differential equations.
- An environment consists of two populations, predators and prey, which interact with each other.The prey are passive, but the predators depend on the prey as their source of food.
- Let $x(t)$ and $y(t)$ denote, respectively, the numbers of individuals in the prey and predator populations at time t. Suppose there is an ample supply of food for the prey and, in the absence of predators, that their rate of growth is $rx(t)$ for some positive r.

Predator-Pray Example

Because of the interaction between the predators and prey, it is reasonable to assume that the death rate of the prey due to interaction is proportional to the product of the two population sizes, $x(t)y(t)$. Therefore, the overall rate of change of the prey population, dx/dt, is given by

$$\frac{dx}{dt} = rx(t) - ax(t)y(t)$$

where a is a positive constant of proportionality.

Predator-Pray Example

- Since the predators depend on the prey for their very existence, the rate of change of the predators in the absence of prey is - $sy(t)$ for some positive s.
- The interaction between the two populations causes the predator population to increase at a rate that is also proportional to $x(t)y(t)$.
- Thus, the overall rate of change of the predator population, dy/dt, is

$$\frac{dy}{dt} = -sy(t) + bx(t)y(t)$$

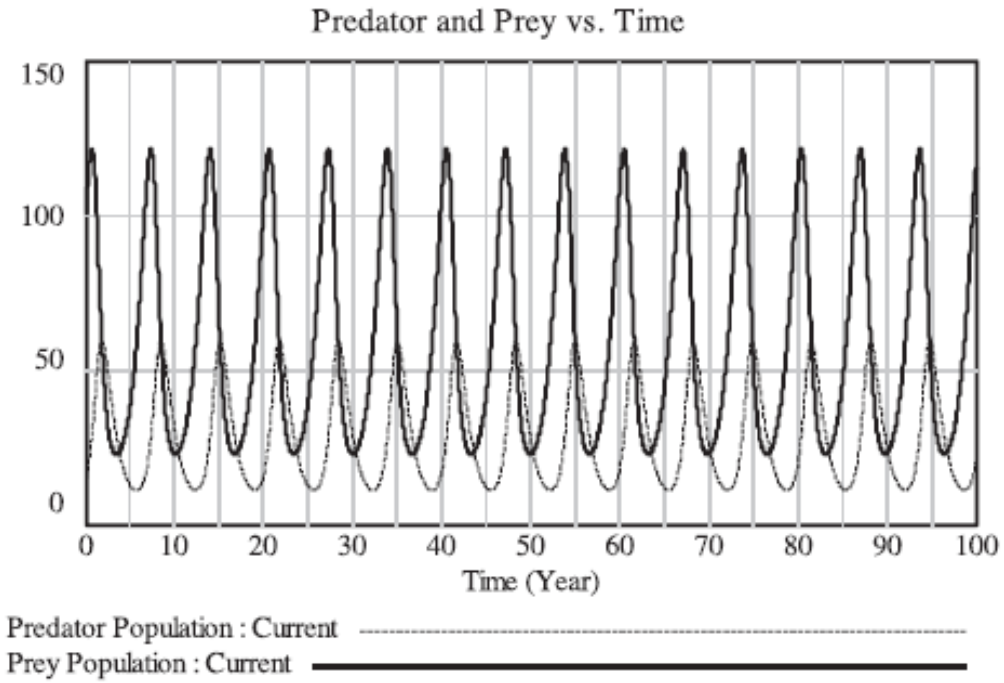
where b is a positive constant.

Predator-Pray Example

- Thus, the prey population can never be completely extinguished by the predators. The solution $\{x(t), y(t)\}$ is also a periodic function of time.
- That is, there is a $T > 0$ such that $x(t + nT) = x(t)$ and $y(t + nT) = y(t)$ for all positive integers n.
- As the predator population increases, the prey population decreases. This causes a decrease in the rate of increase of the predators, which eventually results in a decrease in the number of predators.

Predator-Pray Example

We ran the simulation for 100 years and we plot $x(t)$ and $y(t)$ as a function of t, where the periodicity of $\{x(t), y(t)\}$ can be clearly seen as shown in figure given below:



Solve the Question given below:

Customer No.	Interarrival time (minutes)	Service Time (minutes)
1	-	25
2	0	50
3	60	37
4	60	45
5	120	50
6	0	62
7	60	43
8	120	48
9	0	52
10	120	38

Qs. Average Time in the queue for the 10 jobs?
Qs. Average Processing Time for the 10 jobs?
Qs. Maximum time in the system for the 10 jobs?

Solution

Qs. Average Time in the queue for the 10 jobs?

19 minutes

Qs. Average Processing Time for the 10 jobs?

45 minutes

Qs. Maximum time in the system for the 10 jobs?

112 minutes