```
{ realDomain t ;
  t.min=0;t.delta=0.1;t.max=20;

                         real x(t), y(t);

  when (t=t.min){x=2; y=1;}
                         // ODEs
  x:t =  x-x*y;
                         y:t = x*y-y;
}
```

# Examples of simulation in JSim

# Dynamics of fish in a tank

1. Fishes are growing in a tank that has specific carrying capacity (k).
2. Fishes are regularly removed from tank at a fixed rate.
3. No death

The model:

$$\frac{dx}{dt} = r.x.(1 - \frac{x}{k}) - d$$

*r* = rate constant for growth
*k* = carrying capacity
*d* = rate of removal of fish from tank

## The model in JSim

A JSim model is made of nested components.

Here, **fish_model** is the top level component. You can give any name for this.

This component is of **math** type. Declaring this is essential.

Top component **fish_model** is composed of other components, declared within the parentheses [ **{ }** ]. These parentheses are must.

```
math fish_model
{ realDomain t;
       t.min = 0;t.delta = 0.01;t.max = 100;

  //Define dependent variable
       real x(t);

  //Define parameters
       real r = 1;
       real k = 100;
       real d = 20;

  // Initial value
       when (t = t.min){x = 45;}

  // ODEs
       x:t =  r*x*(1-x/k) - d;
}
```

# The model in JSim

A **realDomain** represents an independent variable. Here it is t.

Each **realDomain** must have a minimum value, maximum value, and step size.

For **t**, these are written here as **t.min**, **t.max** and **t.delta**.

You have to provide specific numerical values for each of these.

**Each statement ends with a semicolon.**

```
math fish_model
{ realDomain t;
        t.min = 0;t.delta = 0.01;t.max = 100;

  //Define dependent variable
        real x(t);

  //Define parameters
        real r = 1;
        real k = 100;
        real d = 20;

  // Initial value
        when (t = t.min){x = 45;}

  // ODEs
        x:t =  r*x*(1-x/k) - d;
}
```

# The model in JSim

x is a dependent variable that varies with t.
So it is written as **`x(t)`** .

It is a **`real`** variable. A "real" variable represents a either constant or a dependent variable.

// is used to mark annotation

```
math fish_model
{ realDomain t;
        t.min = 0;t.delta = 0.01;t.max = 100;

  //Define dependent variable
        real x(t);

  //Define parameters
        real r = 1;
        real k = 100;
        real d = 20;

  // Initial value
        when (t = t.min){x = 45;}

  // ODEs
        x:t =  r*x*(1-x/k) - d;
}
```

# The model in JSim

**`r`**, **`k`**, and **`d`** are parameters or constants. We have to provide numerical values for each.

These parameters/constants are **`real`** variables.

```
math fish_model
{ realDomain t;
        t.min = 0;t.delta = 0.01;t.max = 100;

  //Define dependent variable
        real x(t);

  //Define parameters
        real r = 1;
        real k = 100;
        real d = 20;

  // Initial value
        when (t = t.min){x = 45;}

  // ODEs
         x:t =  r*x*(1-x/k) - d;
}
```

## The model in JSim

To solve the ODE we have to specify the initial value.

Initial time is zero. In other words

**t = t.min**

Value of x at that time is **x = 45**

```
math fish_model
{ realDomain t;
        t.min = 0;t.delta = 0.01;t.max = 100;

  //Define dependent variable
        real x(t);

  //Define parameters
        real r = 1;
        real k = 100;
        real d = 20;

  // Initial value
        when (t = t.min){x = 45;}

  // ODEs
        x:t =  r*x*(1-x/k) - d;
}
```

# The model in JSim

Finally we have to declare the ODE.

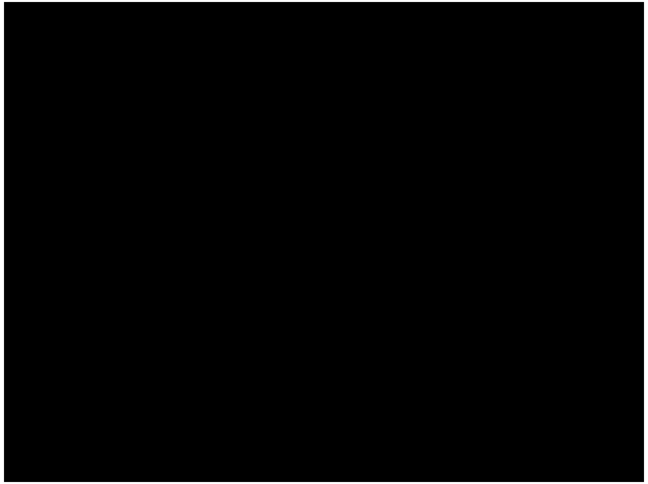
In JSim, dx/dt = **x:t**

So the ODE is declared as :

**x:t =  r*x*(1-x/k) - d;**

```
math fish_model
{ realDomain t;
        t.min = 0;t.delta = 0.01;t.max = 100;

  //Define dependent variable
        real x(t);

  //Define parameters
        real r = 1;
        real k = 100;
        real d = 20;

  // Initial value
         when (t = t.min){x = 45;}

  // ODEs
         x:t =  r*x*(1-x/k) - d;
}
```

# Simulating the model in JSim



# Model with two dependent variables

Predator-prey ecosystem:

Prey population grows by new birth and decreases as predators eat them

Predators eat prey. Population growth of predator depends upon how much they eat. Predators have death.

$$\frac{dx}{dt} = k_1.x - k_2.x.y$$

$$\frac{dy}{dt} = k_2.x.y - k_3.y$$

$x$ = number of prey

$y$ = number of predator

$k_1$ = rate constant for growth of prey population

$k_2$ = rate constant for consumption of prey by predator

$k_3$ = rate constant for death of predators

## Coding in JSim

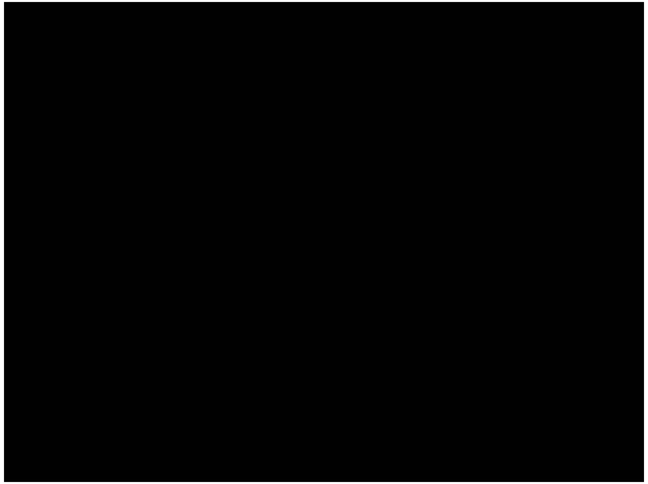
**Two dependent variables are declared.**

**Initial values of two dependent variables declared**

**Two ODEs defined**

```
math predator_prey_model
{ realDomain t ;
        t.min=0;t.delta=0.1;t.max=100;

  //Define dependent variables
        real x(t), y(t);

  //Define parameters
        real k1 = 0.2;
        real k2 = 0.001;
        real k3 = 0.5;

  // Initial values
        when (t=t.min){x=200; y=5;}

  // ODEs
        x:t =  k1*x - k2*x*y;
        y:t = k2*x*y - k3*y;
}
```

# Simulating the model in JSim



**Key points:**

1. JSim code has different components nested one within other.
2. Key components of a ODE model :

    Time: `realDomain t`

    Dependent variables: `real x(t), y(t)`

    Parameter values: `real k1 = 0.2`

    Initial conditions: `when (t=t.min){x=200; y=5;}`

    ODE: `x:t = k1*x - k2*x*y;`

3. Define the main component (model name) as `math`
4. Be careful of proper use of semicolon(`;`) and curly bracket ( `{ }` )