生態模擬: 以C語言為例

Class 09 (2018/05/24)

Applications of Pointer and Array

9.1 Review of address, pointer, and array
9.2 Array and pointer as parameter in function
9.3 Pointer to function (function pointer)
9.4 4th-order Runge-Kutta using function pointer
9.5 Homework for using Pointer to function

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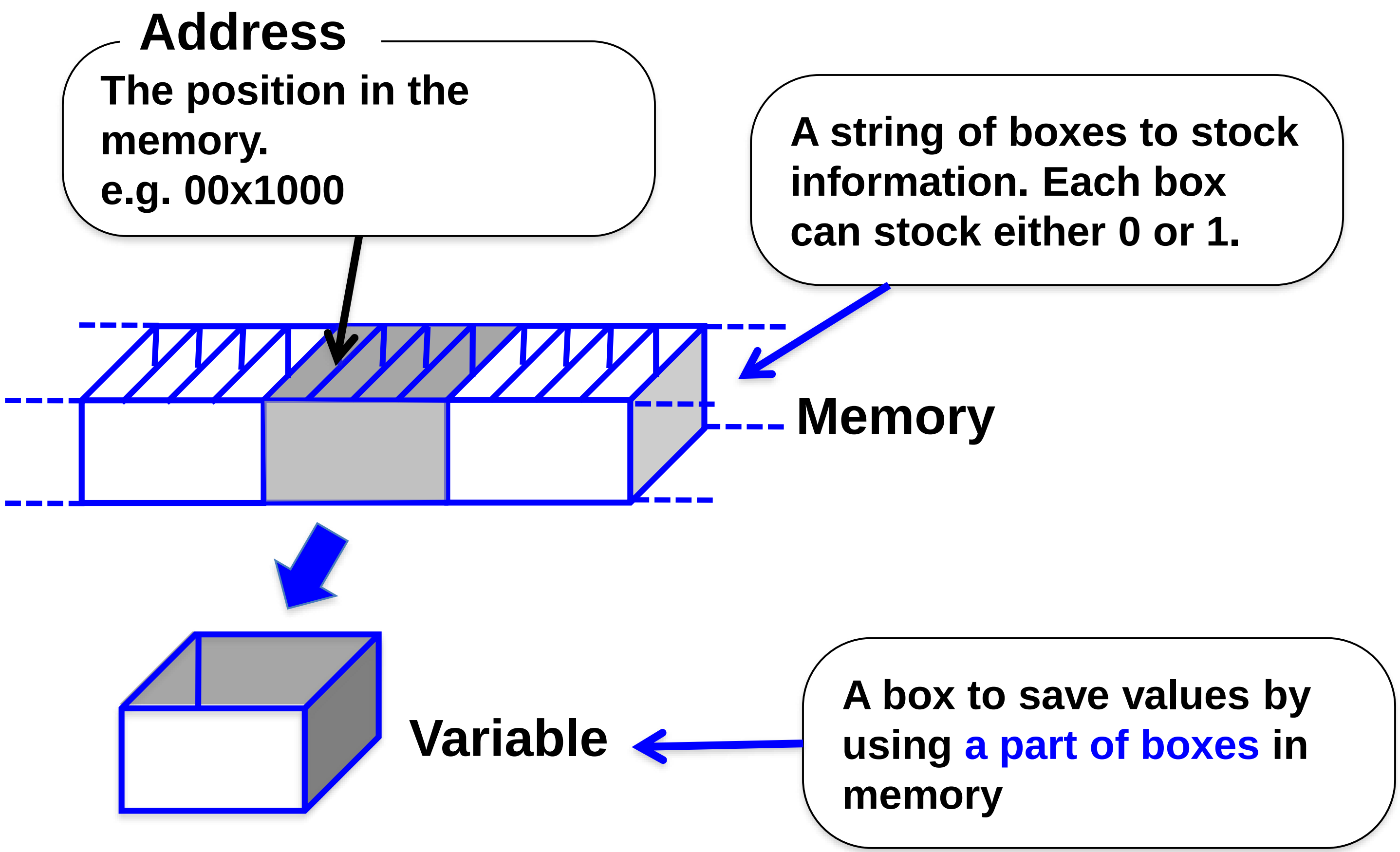
9.1 Memory, Address, and Variable (review)

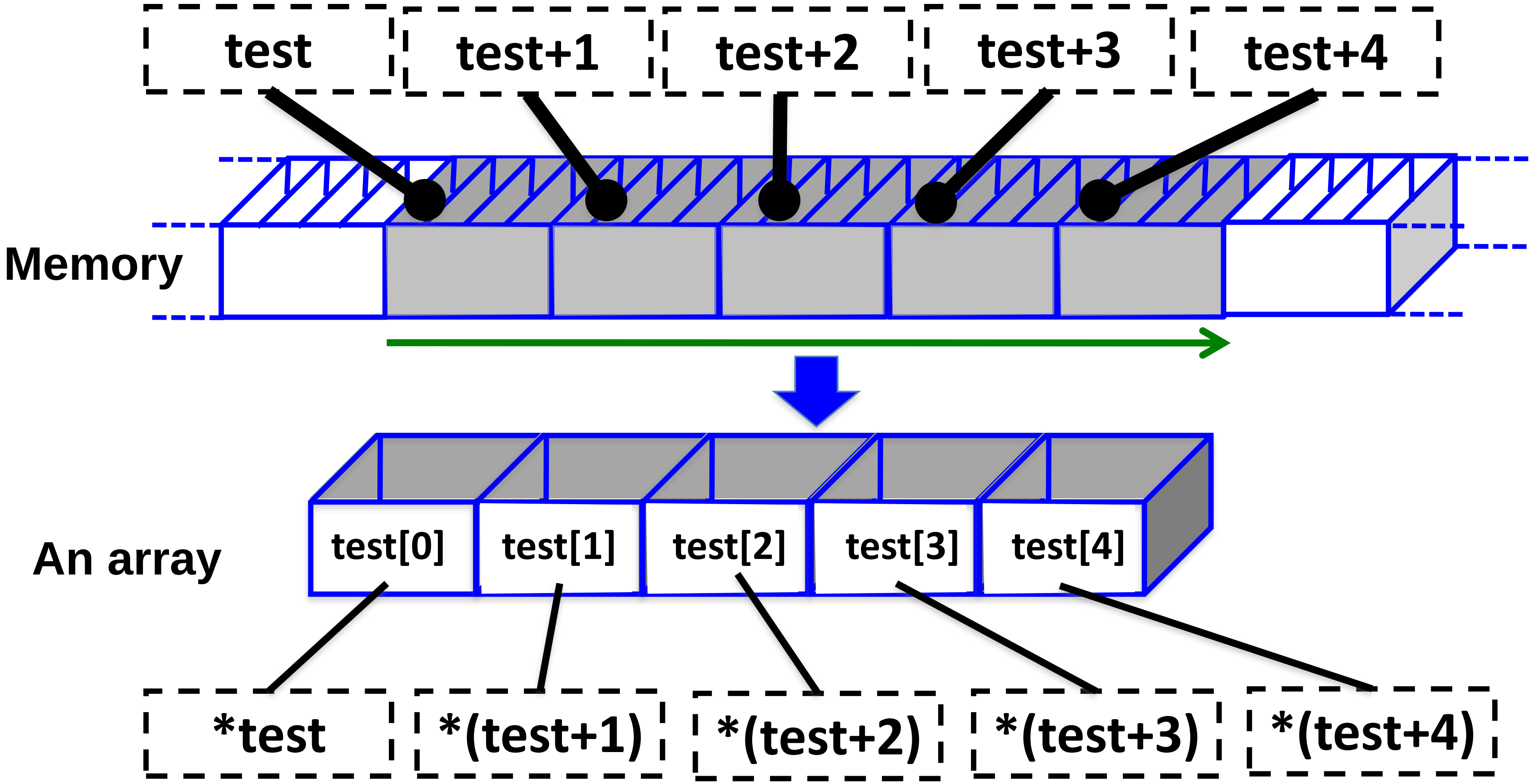
The address in C represents the <u>position</u> in the <u>memory</u>, which is occupied by a <u>variable</u>.



9.1 Array and Pointer (review)

<u>The pointer operators (*, +, -).</u>

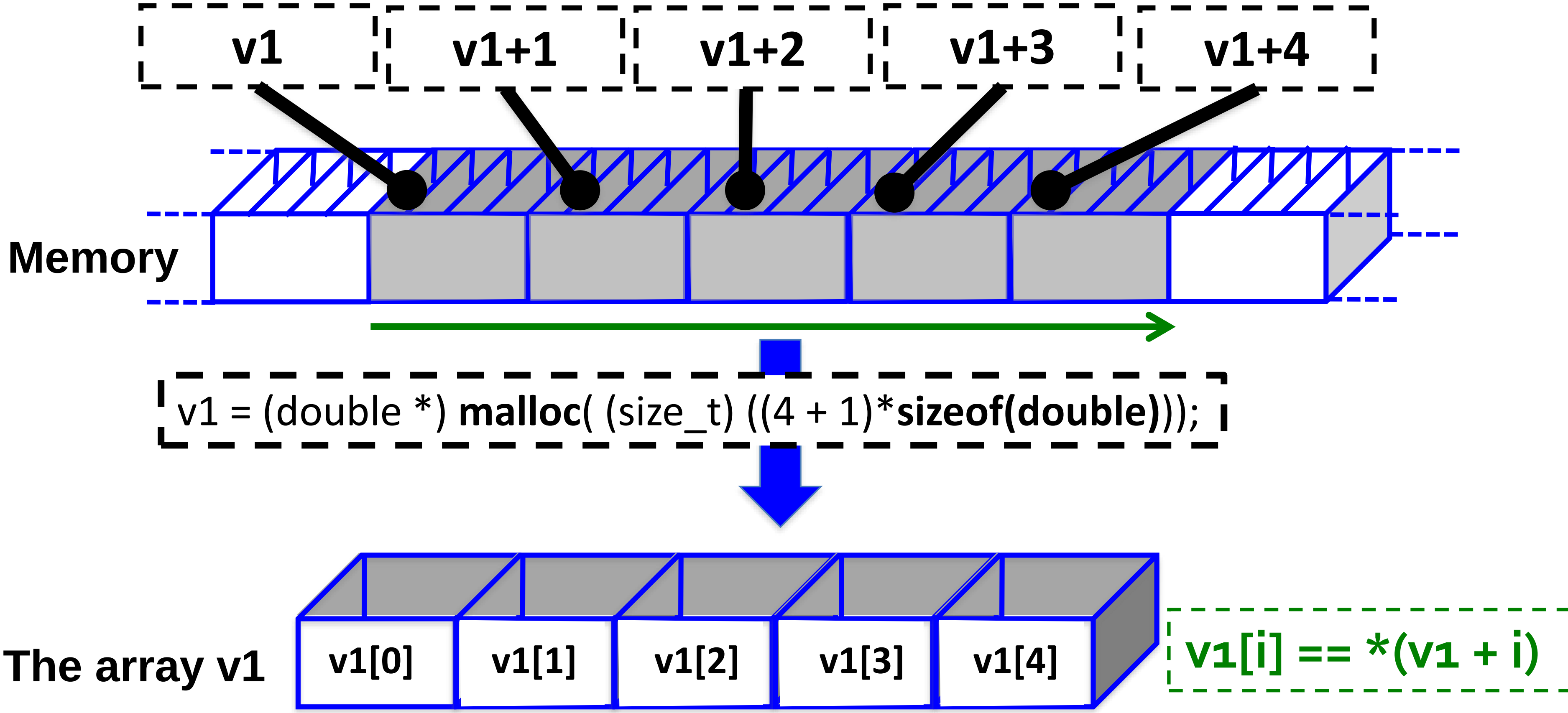
```
double test[5];
```



9.1 Dynamic allocation of memory to array via pointer (review)

The pointer operators (*, +, -) and subscript operator ([])

```
double *v1;
v1 = d_vector(4);
```



9.2 Array and pointer as parameter in function

Array and pointer can be parameter of function. The following 3 functions act in the same way.

```
double avg1(int t[])
{
    int j;
    double sum = 0.0;
    for (j=0; j < 5; j++) sum += t[j];
    return sum/5.0;
}
```

You can call this function in main () using the array name as argument.

```
int test[5];
avg1(test);
arg2(test);
arg3(test);
```

```
double avg2(int *pT)
{
    int j;
    double sum = 0.0;
    for (j=0; j < 5; j++) sum += *(pT + j);
    return sum/5.0;
}
```

```
double avg3(int *pT)
{
    int j;
    double sum = 0.0;
    for (j=0; j < 5; j++) sum += pT[j];
    return sum/5.0;
}
```

9.3 Pointer to function (function pointer)

How to declare a *pointer variable* to function (= function pointer).

構文(Syntax):

Data type of return value (*name of function pointer) (parameter list);

```
int (*pM) (int x, int y);
```

How to use it (1)?

```
int sum(int x, int y);

int main(void)
{
    int num1, num2, num3;
    int (*pM)(int x, int y);              //declaration of function pointer
    pM = sum;                              //assignment of address of sum
    num3 = (*pM) (num1, num2);            //call the assigned function: sum
    ....
```

9.3 Pointer to function (function pointer)

How to use it (2): more useful way

```
int sum(int x, int y);
int prod(int x, int y);

int main(void)
{
    int num1, num2, num3;
    int (*pM)[2](int x, int y);          //declaration of array of function pointer
    pM[0] = sum;                         //assignment of address of sum
    pM[1] = prod;                        //assignment of address of prod
    printf("Do you want to calculate summation (0) or product (1) of 3 & 6?\n");
    scanf("%d", &num1);
    num2 = (*pM[num1])(3, 6);            //call of function using pointer
    printf("Calculated value is %d.\n", num2);

    return 0;
}
```

9.4 Pointer to function (function pointer)

How to use it (3): more useful way in numerical calculations

Function pointer can be parameter of function!!

```
rk4(double y[], ..., void (*diff) (double in[], double out[]));
```

$$\begin{cases} \dfrac{dx}{dt} = r \cdot x\left(1 - \dfrac{x}{K}\right) - a \cdot x \cdot y \\ \dfrac{dy}{dt} = b \cdot x \cdot y - m \cdot y \\ \\ x(0) = 0.1, y(0) = 0.1 \end{cases}$$

Our target!!

9.4 4-th order Runge-Kutta method for ODE

Runge-Kutta method is the same for the multidimensional ODE.

$$\begin{cases} \dfrac{d\vec{N}(t)}{dt} = \vec{f}\left(\vec{N}(t), t\right) \\ \vec{N}(0) = \vec{N}_0 \end{cases}$$

(1) We need to define function to calculate f value.

The 4th order (explicit) Runge-Kutta method is..

$$\overrightarrow{n_{i+1}} = \overrightarrow{n_i} + h \times \frac{1}{6}(\overrightarrow{k_1} + 2\overrightarrow{k_2} + 2\overrightarrow{k_3} + \overrightarrow{k_4})$$

with

$$\begin{cases} \overrightarrow{k_1} = \vec{f}(\overrightarrow{n_i}, t_i) \\ \overrightarrow{k_2} = \vec{f}\left(\overrightarrow{n_i} + \dfrac{h}{2}\overrightarrow{k_1}, t_i + \dfrac{h}{2}\right) \\ \overrightarrow{k_3} = \vec{f}\left(\overrightarrow{n_i} + \dfrac{h}{2}\overrightarrow{k_2}, t_i + \dfrac{h}{2}\right) \\ \overrightarrow{k_4} = \vec{f}(\overrightarrow{n_i} + h\overrightarrow{k_3}, t_i + h) \end{cases}$$

(2) We need to define function for calculating 1-step of Runge-Kutta.

9.4 (1) We need to define function to calculate *f* value.

```
void differential(double time, double in[], double out[]);
double dx_dt(double time, double vr[]);
double dy_dt(double time, double vr[]);

int j_x = 1;   //define index as global variable
int j_y = 2;   //define index as global variable
double a = 1.0;  //define model parameter as global
…
int main(void)
{
     ….
}

void differential(double time, double in[], double out[]);
{
     out[j_x] = dx_dt(time, in);
     out[j_y] = dy_dt(time, in);
}
double dx_dt(double time, double vr[])
{
    return r*(1.0 – vr[j_x]/K) -  a*vr[j_x]*vr[j_y];
}
```

```
int main(void)
{
       double t = 0.0;
       double deltat = 1.0e-3;

       double *v = d_vector(2);
       double *dfdt = d_vector(2);
       …
       v[j_x] = 1.0; //initial density
       v[j_y] = 2.0; //initial density
       …

       differential(t, v, dfdt);
       rk4(…);                      1-step
       t += deltat;

      ….
      free_d_vector(v);
      free_d_vector(dfdt);
      return 0;
}
```

9.4 (2) We need to define function for calculating 1-step of Runge-Kutta

```
void rk4(double y[], double dydt[], int n, double t, double h, double yout[],
void (*diff) (double, double [], double []))
{
        int i;
        double th, hh, h6, *dym, *dyn, *dyt, *yt;

        dym = d_vector(n);
        dyn = d_vector(n);
        dyt =d_vector(n);
        yt = d_vector(n);
        hh = h*0.5;
        h6 = h/6.0;
        th = t + hh;
        for (i=1;i<=n;i++) yt[i] = y[i] + hh*dydt[i];
        (*diff)(th, yt, dyt);
        for (i=1;i<=n;i++) yt[i] = y[i] + hh*dyt[i];
        (*diff)(th, yt, dym);
        for (i=1;i<=n;i++) yt[i] = y[i] + h*dym[i];
        (*diff)(t+h, yt, dyn);

        for (i=1;i<=n;i++)  yout[i] = y[i] + h6*(dydt[i]+2.0*dyt[i]+2.0*dym[i] +
dyn[i]);

        free_d_vector(yt);
        free_d_vector(dyt);
        free_d_vector(dym);
        free_d_vector(dyn);
}
```

$$\vec{k}_1 = \vec{f}(\vec{n}_i, t_i)$$

(already calculated)

$$\vec{n}_i + \frac{h}{2}\vec{k}_1$$

$$\vec{k}_2 = \vec{f}\left(\vec{n}_i + \frac{h}{2}\vec{k}_1, t_i + \frac{h}{2}\right)$$

$$\vec{n}_i + \frac{h}{2}\vec{k}_2$$

$$\vec{k}_3 = \vec{f}\left(\vec{n}_i + \frac{h}{2}\vec{k}_2, t_i + \frac{h}{2}\right)$$

$$\vec{n}_i + h\vec{k}_3$$

$$\vec{k}_4 = \vec{f}(\vec{n}_i + h\vec{k}_3, t_i + h)$$

```
int main(void)
{
        ...
        differential(t, v, dfdt);
        rk4(v, dfdt, 2, t, deltat, v,
differential);
        t += deltat;
       ....
}
```

9.4 Application to a prey-predator model

Numerically solve the following equations with the Runge-Kutta method.

$$\begin{cases} \dfrac{dx}{dt} = r \cdot x\left(1 - \dfrac{x}{K}\right) - a \cdot x \cdot y \\ \dfrac{dy}{dt} = b \cdot x \cdot y - m \cdot y \\ \\ x(0) = 0.1, y(0) = 0.1 \end{cases}$$

Our target!!

$$r = 1.0, K = 1, a = ?, b = ?, m = ?$$

9.5 Application to a prey-predator model

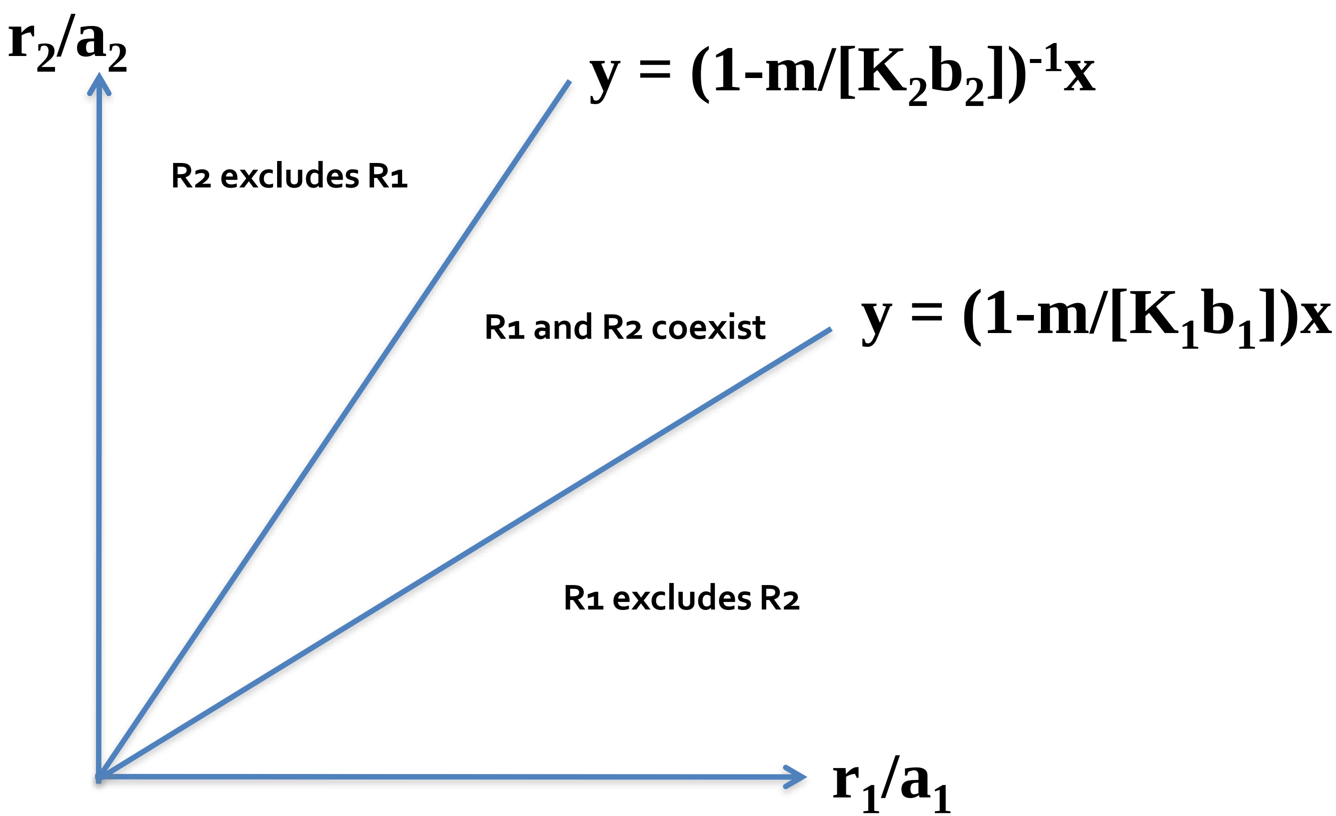
Numerically solve the following equations (an apparent competition) with the Runge-Kutta method and show the temporal dynamics of them in three cases (R1 excludes R2, R2 excludes R1, and R1 and R2 coexist).

$$
\begin{cases}
\dfrac{dR_1}{dt} = \left\{ r_1 \left(1 - \dfrac{R_1}{K_1} \right) - a_1 P \right\} R_1 \\
\dfrac{dR_2}{dt} = \left\{ r_2 \left(1 - \dfrac{R_2}{K_2} \right) - a_2 P \right\} \boldsymbol{R}_2 \\
\dfrac{dP}{dt} = \left(b_1 R_1 + b_2 R_2 - m \right) P \\
R_1(0) > 0, R_2(0) > 0, P(0) > 0
\end{cases}
$$

Homework !!

9.5 Application to a prey-predator model

Numerically solve the following equations (an apparent competition) with the Runge-Kutta method and show the temporal dynamics of them in three cases (R1 excludes R2, R2 excludes R1, and R1 and R2 coexist).



Homework !!