1st model example.

Phenology model of insect (carrot Weevil).

Description and practical work with R

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carrot Weevil

Biology and protection solutions

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carrot

- *aucus carota subsp. sativus*
- one of the ten most economically important vegetable crops in the world

Production of carrots and turnips – 2013

Country	Production (millions of tonnes)
China	16.8
Uzbekistan	1.6
Russia	1.6
United States	1.3
Ukraine	0.9
World	**37.2**

Source: FAOSTAT of the United Nations[43]

Carrot Weevil - *Listronotus oregonensis*

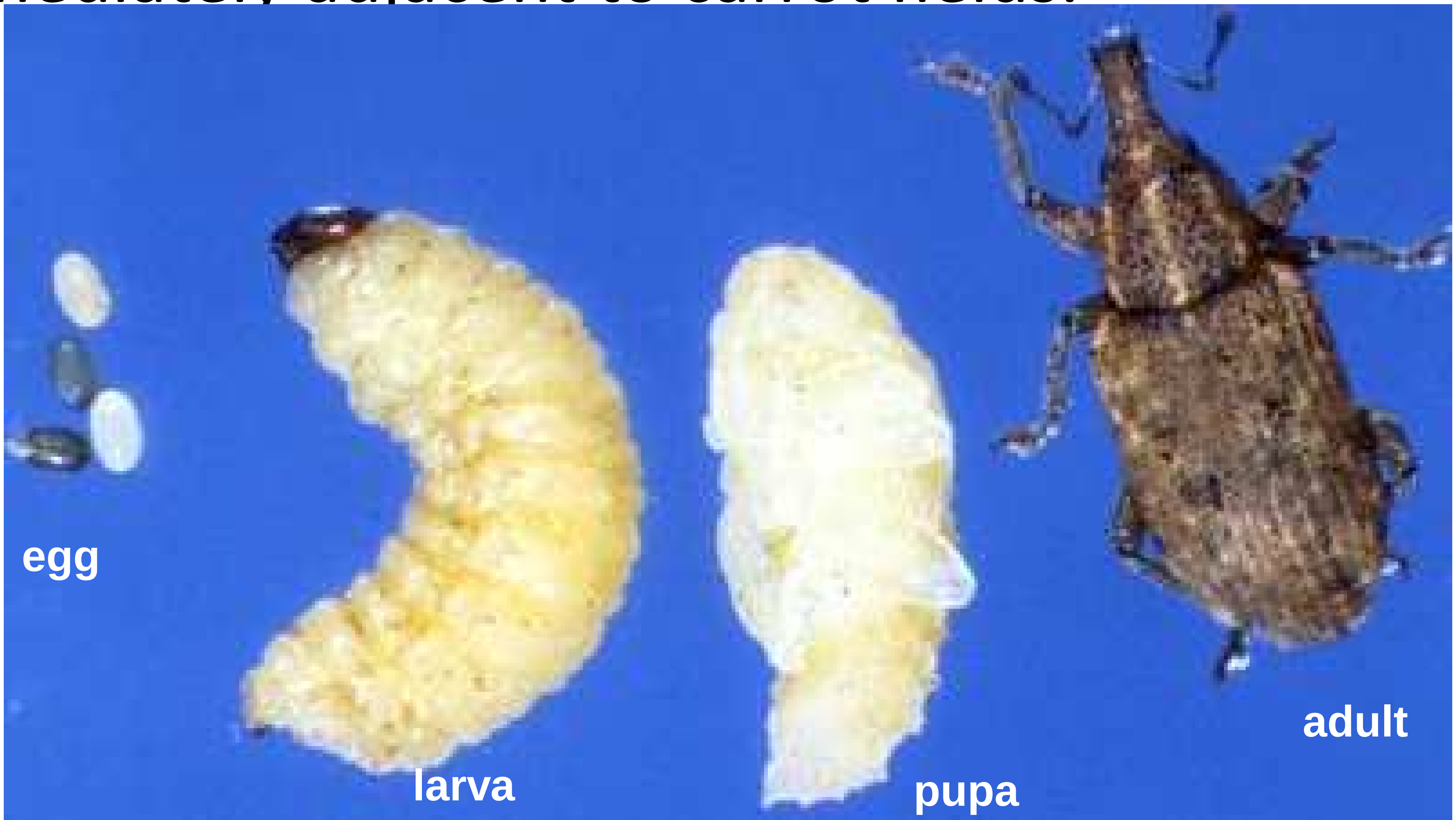
- Region: This weevil can be found throughout eastern and central North America (other country ?).
- Physical Description:
  - 0.5 cm long
  - dark brown to coppery
  - with a hard shell.
- This pest attacks :
  - carrot, celery, dill, parsley, and parsnip plants
  - by boring into the tops of the carrot roots or directly into the carrot heart.
  - destroy most of the plant's tissue with a zigzag pattern.

Carrot weevil damage

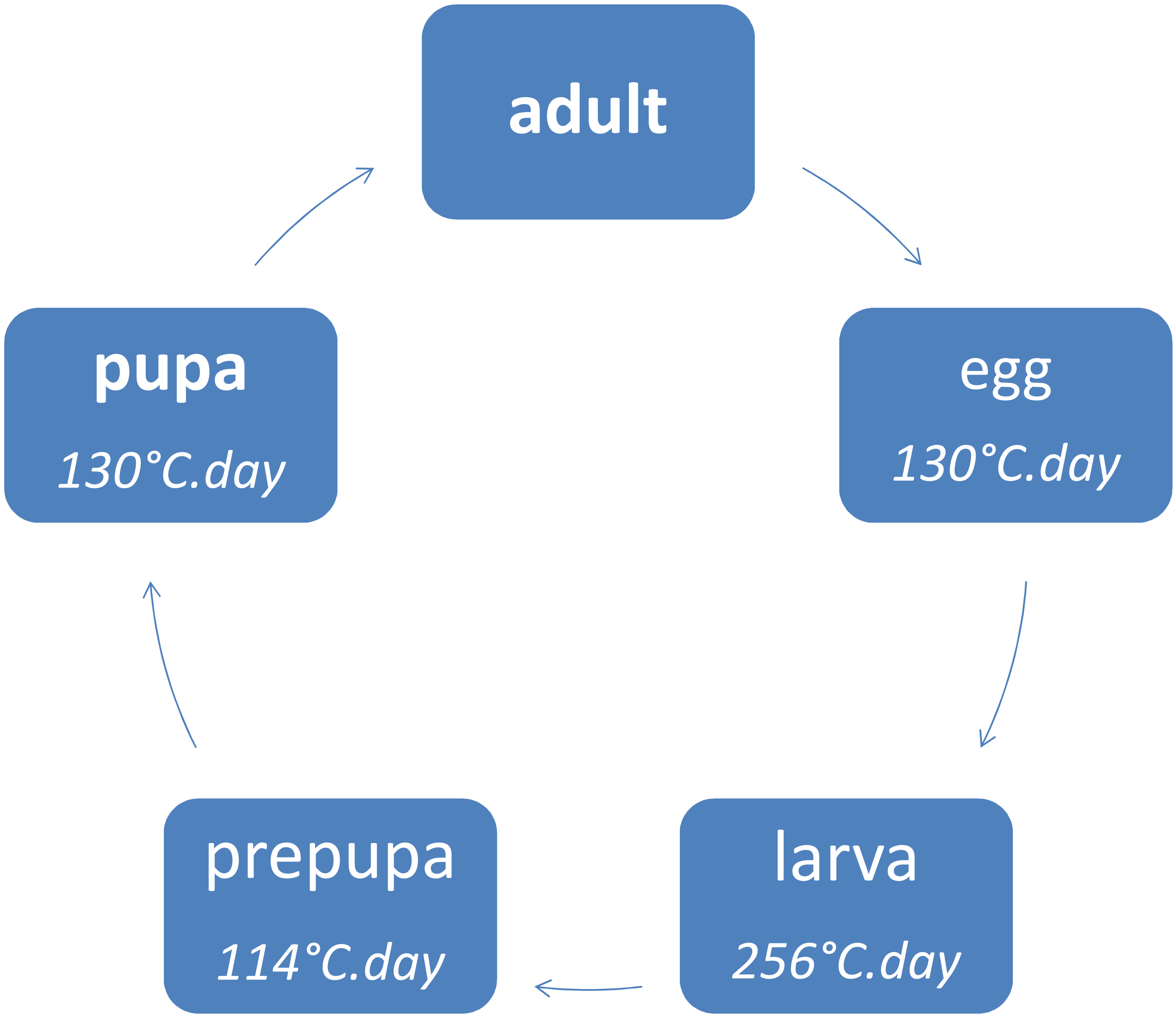
damaged **no damage**

life cycle

- two generations each year
- overwinters as an adult in grass or garden debris immediately adjacent to carrot fields.



life cycle



Generation time (egg to adult) : 630 °C.day

Chemical control

- Fungicides available: several families
- effectiveness in prevention (before infection)
- Curatively on infected culture, may also stop the disease for 3 to 5 weeks depending on the fungicide, the dose and conditions

⇒ **Importance of treatment positioning to maximize efficiency**

Biological control

Based on nematodes

cultural practices

clean up, rotation and soil preparation

- If debris, high grass, weedy areas next to crops or gardens are clean up, the weevil won't be able to find a cozy place to overwinter.
- Crop rotation is helpful in the prevention of this insect.
- In the spring, destroy any grubs in the soil by a deep cultivation in the area where you will be planting.

Phenology model of insect (carrot Weevil).

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Objectives

- **Understand the formalism.**
- **Write the simulator for this model in R.**
- **Use the model for different objectives.**

Description of the model

- thermal time : a very common variable used in agronomy and in crop protection.
- Phenology models predict timing of events base on thermal time.
- For crop protection, it’s often used for calculate the development of pests such as insects, whose development depends on temperature of their environment.

definition of thermal time

- A simple definition of thermal time (TT) is the sum each day of daily mean temperature (Tmean) minus Tbase.
- If the difference is negative (if daily mean temperature is below Tbase) then the temperature sum that day is 0.
- The units of thermal time are °C.day

Equation of the model

$$TT = \sum_{day=1}^{duration} \max(Tmean_{day} - Tbase\,;0) * 1$$

Application to Carrot Weevil

- Carrot Weevil (*Listronotus oregonensis*) develops only when temperature is above 7.0°C
- 7.0°C is the Lower Developmental threshold, usually noted Tbase or base temperatuure.

Lets start in R

- *a) Write an R function taking as argument a vector of temperatures and returning the TT on the last day of the input.*
- *Use a loop (for …) and a condition (if… else…) for it. Write a main program that executes the function.*

R needs to be installed (an older version is Ok !)

https://cran.r-project.org/bin/windows/base

If not too much familiar with R, I propose to use Rstudio : https://www.rstudio.com/products/rstudio/download

- *b) Modify the previous function to store the TT values at each time step in a vector called TT. Before storing the TT values, you must define the TT vector. You can create a vector TT where the using the instruction TT <- rep(NA, duration). Also, modify the function so that Tbase is also an argument.*
- *Bravo! You have written your first dynamic model with R!*

- *<u>Supplementary questions</u>*
- *c) We have information on thermal time accumulation required for each stage of development (Eggs: 130.0 °C.day; Larvae: 256.0 °C.day; Prepupae: 114.0 °C.day; Pupae: 130.0 °C.day; Generation time - egg to adult :630.0 °C.day). Use this information to propose a complete phenology model for Carrot Weevil.*
- *d) Propose a simpler function that does not have a loop and does not have a condition.*

Run the code on weather data

- Use the European JRC data extracted for Toscana :

File :

test_toscane_ver2015-1_0_6325_247018277.csv

GRID_NO	LATITUDE	LONGITUDE	ALTITUDE	DAY	TEMPERATUI	PRECIPITATIO
73109	44.52363	9.89329	534	19750101	3.1	0
73109	44.52363	9.89329	534	19750102	2.6	0
73109	44.52363	9.89329	534	19750103	2	0
73109	44.52363	9.89329	534	19750104	2.3	0
73109	44.52363	9.89329	534	19750105	2.4	0

How to structure the code of the function?

- creation of state variable as vector
- initialization of state variable
- Simulation loop
  - Calculate rates of change of state variables (dTT)
  - Update state variables *
- End simulation loop
- Return results