I WANT TO LIVE FOREVER...

2D. ORGANISMS AND THEIR ENVIRONMENT

You are a researcher in the LifeSpan project. Like all of the other students in the class, you are conducting research on ageing. Your specific research is on the role played by environmental factors in ageing. Ultimately you will be presenting your results to the rest of the class. The following assignments will help you to study the results, and to prepare your presentation.

Have fun!

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De Praktijk

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Assignment 1. Different phenotypes in insects

Phenotypes (all of an organism's observable characteristics) are determined by two things: the genotype and the environment. The genotype is fixed from the moment of fertilisation, whereas environmental factors continue to have an influence throughout the organism's lifetime.

1. Environmental factors also influence illness and ageing. Name four environmental factors that can affect human lifespan. Tip: think back to the game that you played – *I want to make babies!*

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An organism divides its energy between maintenance ('long life') and reproduction ('creating offspring'). The optimum balance between these two will also depend on the environment. Under certain circumstances it is sensible to invest most of your energy in reproduction. In another environment, the opposite is true.

Eastern Africa has roughly two seasons per year: a dry season (from May to November) and a wet season (from December to April). During the wet season, there is lots of plant growth and food for butterflies. During the dry season, many plants are withered, and there is little food. In this area, butterflies of the species *Bicyclus* can be found all year round. There are three generations per year: two short-lived generations during the wet season, and one long-lived generation in the dry season (see Figure 1). In addition to a difference in lifespan, these butterflies also show differences in behaviour and the patterns on their wings. This phenomenon is known as *phenotypic plasticity*. The temperature during larval development can be seen as a predictor for future conditions, to which the butterfly adapts its metabolism, behaviour and wing pattern. The genotype stays the same.

Phenotypic plasticity is the ability of an organism to adapt its phenotype to circumstances without changing the genotype.

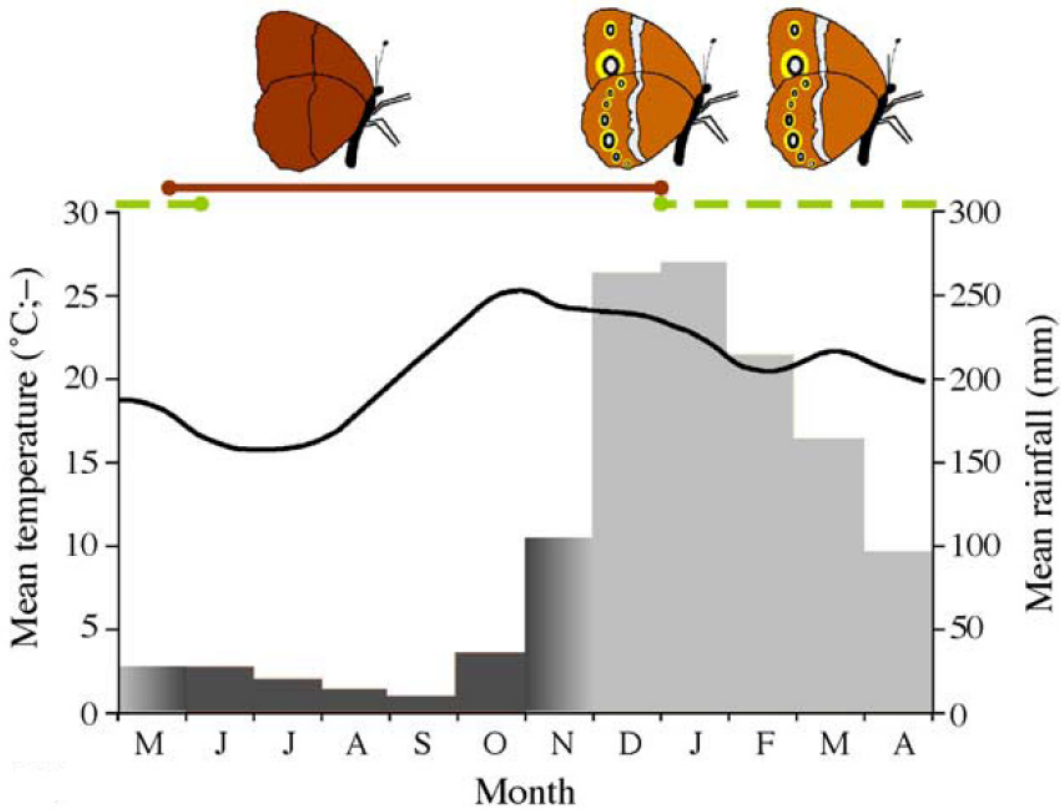

Figure 1. Phenotypic plasticity among Bicyclus butterflies. The graph indicates the average temperature (line) and average rainfall (bars). From: Brakefield et al. (2005).

2. Laboratory experiments have shown that the ambient temperature during larval development is what determines the phenotype of the adult butterfly. Look at the temperature graph in Figure 1, and the images of the phenotypes above. Which temperature belongs to which phenotype? Cross out answers that do not apply.

high temperature during larval development leads to the phenotype from the dry / wet *season*

low temperature during larval development leads to the phenotype from the dry / wet *season*

3. The butterflies in the dry season invest less energy in reproduction (and more energy in maintenance and repair) compared to the wet-season variety. As a result, it takes about six months before they start to produce offspring. Explain why the strategy of living longer and later reproduction is beneficial during the dry season, but not during the wet season.

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An even more extreme example of phenotypic plasticity can be observed among insects such as ants and bees. Most ant species exhibit different phenotypes (queens, workers and males). Each phenotype has more or less the same genotype but differs in terms of appearance, behaviour, and... lifespan.

4. Watch the following video:
Laurent Keller 1 – Phenotypes and gene expression in ants

Laurent Keller explains that the difference between the various phenotypes is primarily caused by differences in gene expression (i.e. protein synthesis). Table 1 gives a number of genes that are either expressed more in queens than in workers, or the other way around.

Table 1. Differences in gene expression between queens and workers (in L. niger). From: Gräff et al. (2007).

gene	encodes	active primarily in
Ln96_2	the protein vitellogenin, which plays a role in (a) the development of egg cells, and (b) the functioning of the immune system	queens
Ln252_3	proteinase inhibitors, enzymes that aid defence against micro-organisms	queens
Ln385_5	a pheromone receptor, a protein that bonds with pheromones (perfumes) exuded by the queen; these pheromones have a strong influence on the behaviour of the workers	workers

5. Three different substances that can be found in the cells of ants are DNA, mRNA and proteins (see Figure 2). Which two of these can be analysed to gather information on gene expression? Explain.

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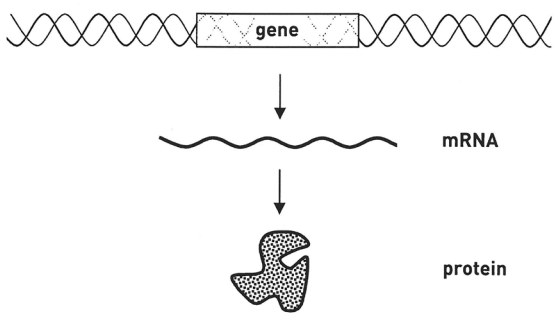

Figure 2. Gene expression. Diagram: C. Geraedts.

The differences in gene expression between the various phenotypes are probably present as early as the larval development stage. Research on bees has shown that the food given to a larva determines whether it will become a queen or a worker (see Figure 3).

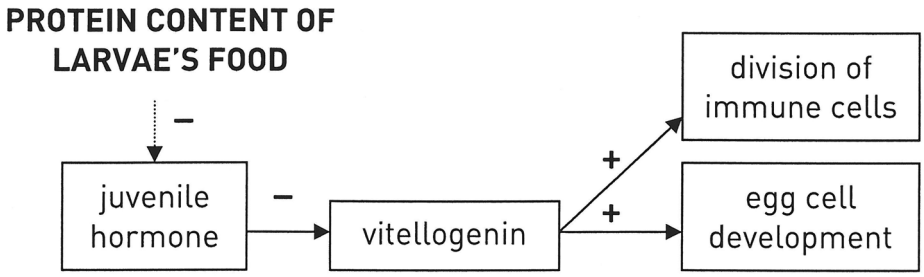

Figure 3. The regulation of phenotypic plasticity in bees.

6. Look at the diagram in Figure 3. Which type of food will cause a larva to turn into a queen? Cross out the answer that does not apply.

food with lots of proteins / food with few proteins

7. Watch the following video:
Laurent Keller 2 – A compromise between reproduction, maintenance and protection

Organisms need to strike a balance between investing energy into repairing damage, and investing in reproduction. In this regard, ants show a strange phenomenon. The queen lives by far the longest (30 years), and is also the only one who reproduces (at a very fast rate).

8. What major advantage does the queen have compared to the workers and males?

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Assignment 2. Undernourishment and obesity

According to biochemist David Barker, a certain degree of phenotypic plasticity is also evident in humans. Research has shown that there is a link between malnutrition during embryonic development, and glucose regulation later in life. This has been demonstrated in people who were *in utero* (i.e. unborn babies) during the Dutch 'winter of hunger' in 1944/45. Barker's theory is known as the *thrifty phenotype hypothesis*. This theory is summarised in the diagrams below.

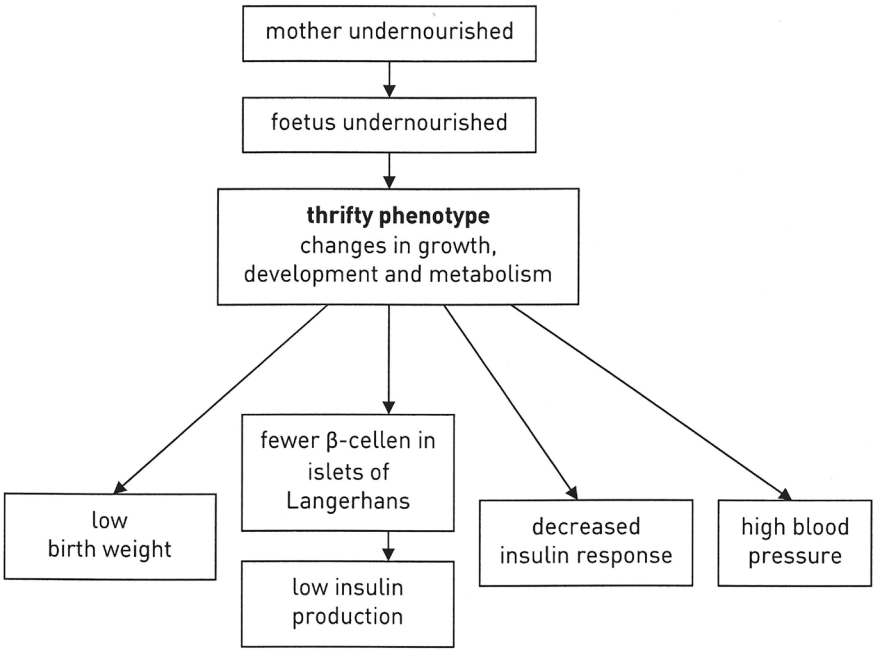

Figure 4. The emergence of a thrifty phenotype as the result of a lack of nourishment during embryonic development. From: Hales & Barker (2001).

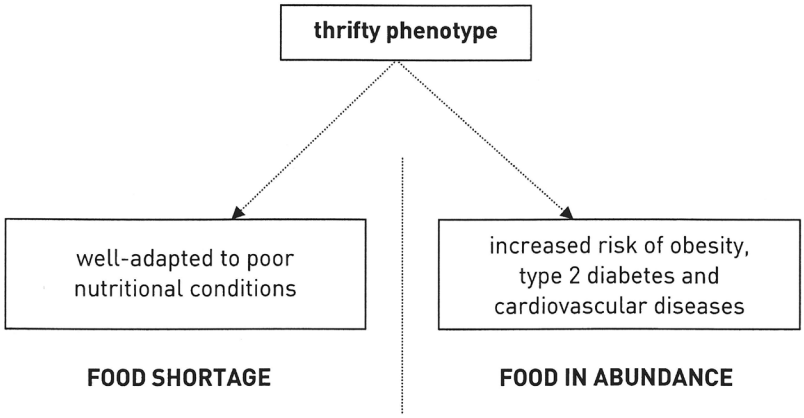

Figure 5. The consequences of a thrifty phenotype in times of food shortage or abundance. From: Hales & Barker (2001).

1. People with a 'thrifty phenotype' produce less insulin (see Figure 4). Their bodies' response to this hormone is also reduced. What happens to the glucose levels in their blood?

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2. In the case of the butterflies (see assignment 1), phenotypic plasticity has a clear advantage: each butterfly develops the phenotype that is best suited to the prevailing conditions. A thrifty phenotype (in humans) can also be viewed as preparation for future circumstances. Explain.

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3. The thrifty phenotype hypothesis creates a link between undernourishment during embryonic development, and the development of obesity (being overweight) later in life (see Figure 5). Explain why the thrifty phenotype hypothesis cannot be used as the only explanation for increased obesity rates.

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Assignment 3. Maternal care

Food and temperature are not the only environmental factors that affect organisms . The presence or absence of members of the same species can also be important. The care provided by the mother (and sometimes the father) during the initial stage of mammals' lives is also an important factor.

1. Watch the following video:
Ron de Kloet 2 – Research on stress reactivity in animals

2. Ron de Kloet describes a study on the influence of maternal care among rats, primarily care (attention, licking, food, etc.) during the very first stage of life. In the video, he names a number of the consequences of receiving a lot of (or very little) maternal care. Complete the table below. Watch the video again if you wish.

	response to emotions and stress	response to an unfamiliar environment
rats that received a lot of maternal care		
rats that received little maternal care		

3. Of course, maternal care also applies to humans. Compared to other animal species, human babies need to be cared for for a relatively long period of time. However, research has shown that it does not really matter to the baby whether it receives care from the mother or from someone else (e.g. the father or grandmother). What advantage does this offer?

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Assignment 4. The LifeSpan conference

At scientific conferences, researchers from a range of universities come together to share information and discuss research results. You are going to do this too. To conclude this assignment you will hold a kind of scientific conference, in which you will give a short presentation on the subjects you have studied thus far. You will also write a short proposal for further research.

The presentation will consist of three sections:

A. Phenotypic plasticity among insects

Use the diagram on page 10 to explain the following:
- what phenotypic plasticity is,
- that there is no difference in genotype, only in gene expression.

B. The thrifty phenotype hypothesis

Use the diagrams on page 11 to explain the following:
- what causes the emergence of a thrifty genotype and the associated characteristics,
- that the thrifty phenotype hypothesis alone does not explain the increase in the number of people with obesity and diabetes.

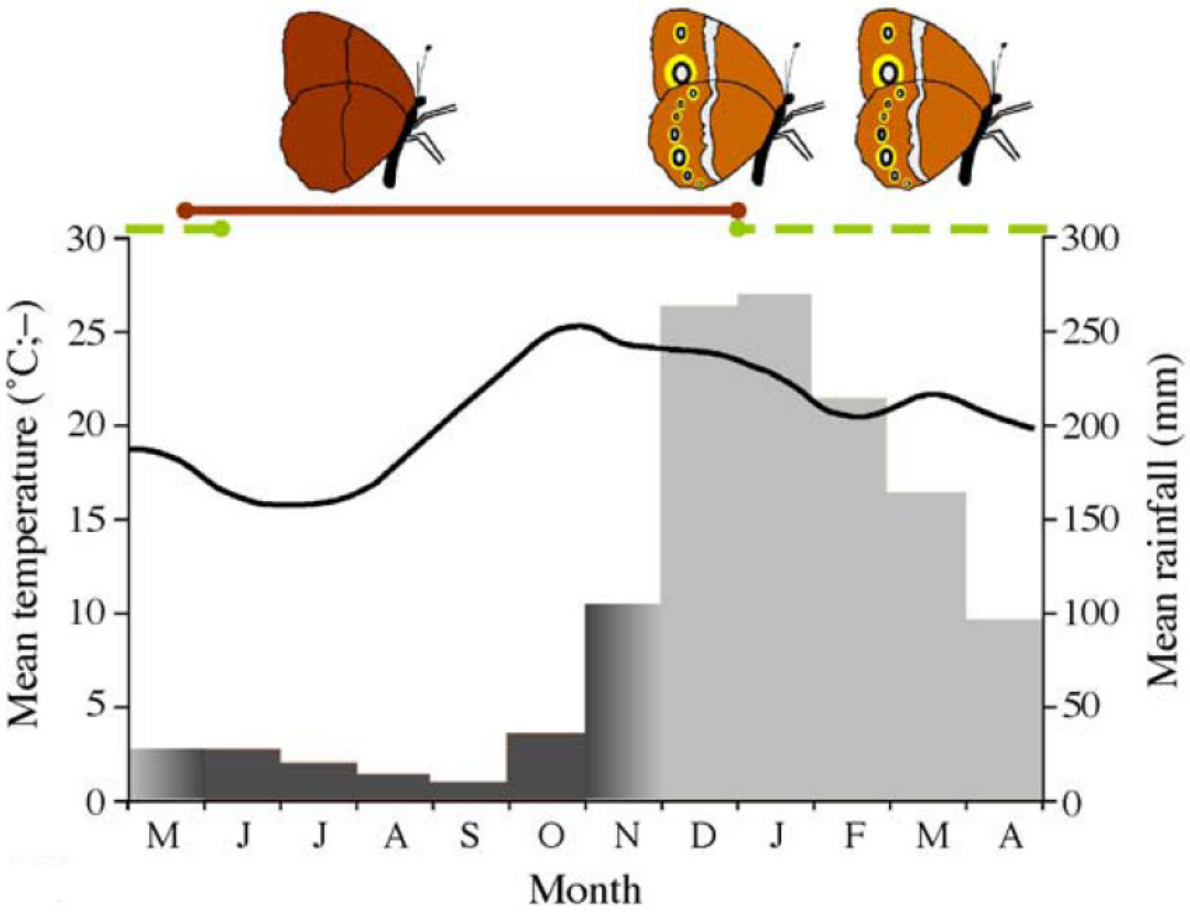
C. Proposal for further research

You wish to research the link between birth weight, diet and obesity later in life among humans. Explain why you include birth weight as a variable in your research. Briefly describe the steps you will take to answer your research question (see the template on page 12).

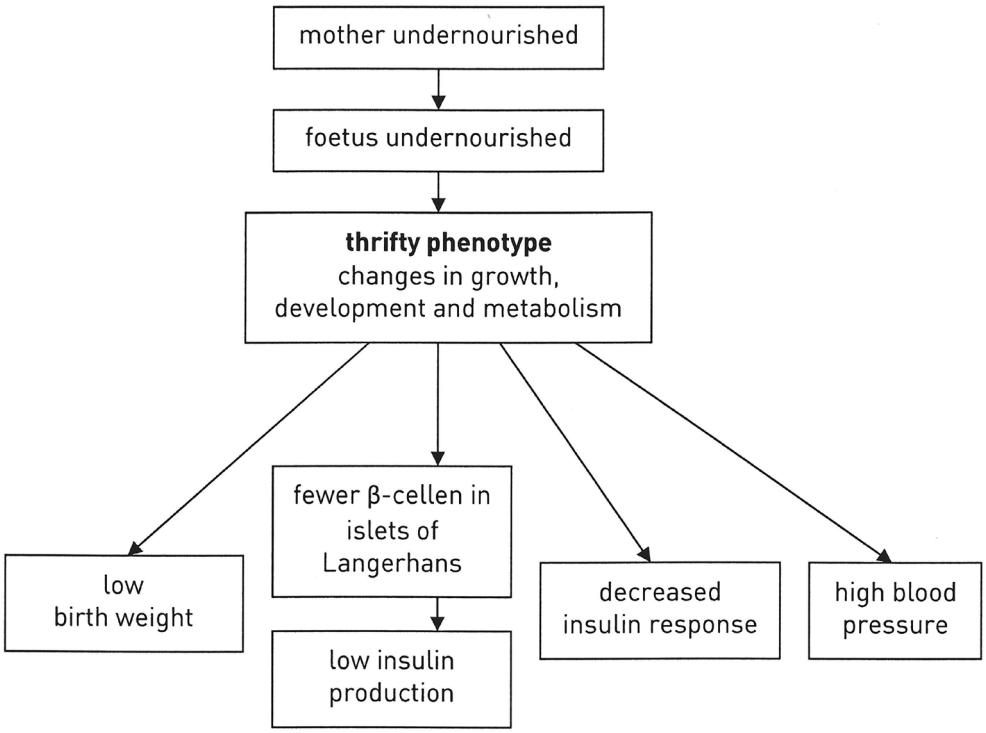
Preparation
PowerPoint slides have already been made for you, containing the images on pages 10 and 11. Use these copies to make your notes. Write your research proposal using the template on page 12. Make a rough copy first if necessary.

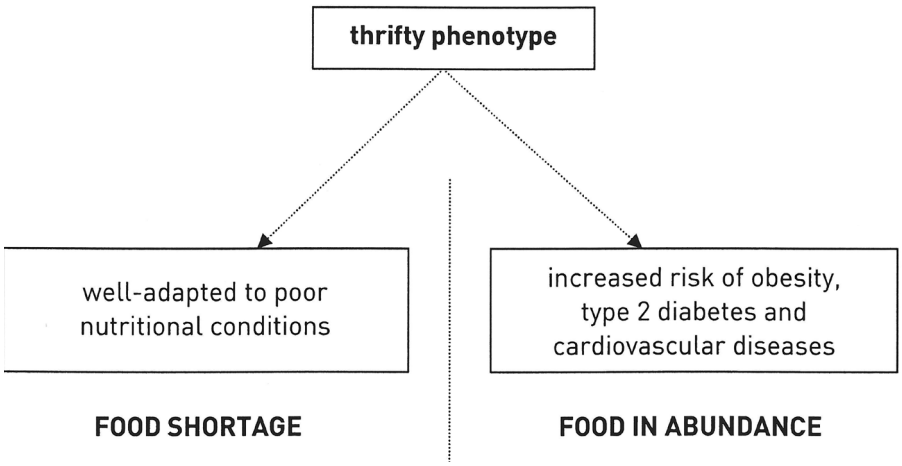
The conference
Using your PowerPoint slides, give a short presentation on what you have learned. You may refer to your notes if you wish. Also present your research proposal to the rest of the class. The teacher will determine whose turn it is.

A. Phenotypic plasticity among insects



B. The thrifty phenotype hypothesis





C. Research proposal

Title of research project
Introduction (approx. 50 words)
Research question
Hypothesis
Research plan (including materials and methods)