Calcium homeostasis

Lesson that shows the functioning and essence of calcium in the human body.

DynaLearn level 4 | Version 1.0

Summary	
Understanding the calcium balance is important because calcium is needed for various processes in the body. Calcitonin regulates the calcium balance by storing calcium in bones and preventing calcium excretion via the kidneys and absorption in the intestines. In this lesson, the student learns how the body regulates calcium to maintain health and prevent diseases such as rickets.	
Given name	
Surname	
Class	
Date	
Comments by teacher	

1. Introduction

In this lesson you will make a model of the calcium homeostasis of a person. Calcium is important for the construction and maintenance of your bones and teeth. To understand the calcium balance, we would like to ask you to study Figure 1 carefully.

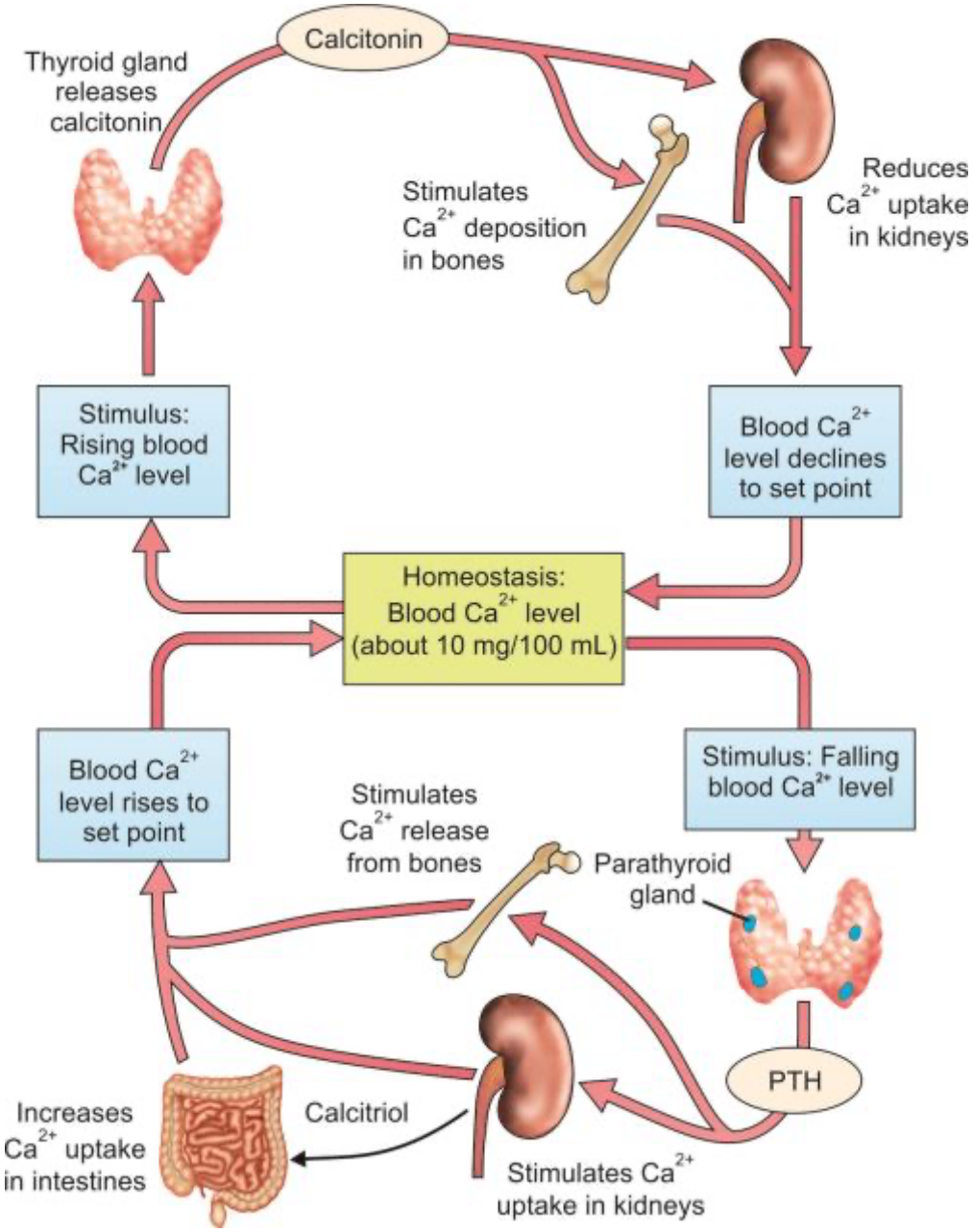


Figure 1. The calcium balance of a person

2. Starting DynaLearn

There are several ways to log in. Use one of the two options below. Then check whether the login was successful (see 'Let's check').

Via a code:

1. Go to DynaLearn (https://create.dynalearn.nl/).
2. Click on 'log in with code', at the bottom left.
3. Enter the project code and your (school) email address.
4. Copy the code from the confirmation email received from *dynalearn.nl* (see spam folder if needed) and fill in the other details.
5. Log in to DynaLearn.

By email invitation:

1. Copy the login details from the invitation email received from *dynalearn.nl*.
2. Go to DynaLearn (https://create.dynalearn.nl/).
3. Log in to DynaLearn.

Let's check!
After logging in, you will automatically enter the workspace of the assignment. You can recognize it by the gray question mark on the right side of the screen  . Is the question mark missing? Then first:

- In Dynalearn, click  . Click on 'Select norm model'.
- Choose 'Calcium homeostasis' and press 'Load'.

Save model file and start:

1. Click on  top left. Change the name to 'Calcium homeostasis' and click 'Save'.
2. How do you proceed? Follow the steps in this workbook. Note! You can't skip steps. Ask for help if you get stuck. The video function  in Dynalearn shows how a model ingredient can be made. The boxes contain a brief explanation about the model ingredient. Put a check mark √ next to the step you performed. This way you keep track of where you left off.

3. Calcitonin and Ca^{2+} in bones and blood

In the model, you will first make the connection between calcitonin and the amount of Ca^{2+} in the bones and blood (see Figure 1).

1. Read Box 1.

Box 1. Entity and quantity.

An entity is usually a physical thing in a system (e.g., car, human).
A quantity is a measurable property of an entity (e.g., temperature, length).

2. Create the entity *Bones* (see →).

3. Make the quantity Ca^{2+} of the entity *Bones* (see →).

4. Read Box 2.

Box 2. Change of a quantity.

A quantity can change. This is indicated by δ ▲ Ø ▼ . The delta symbol (δ) is the mathematical sign for change (also called the derivative). The down arrow (▼) is a decrease, the zero (Ø) is constant and the up arrow (▲) is an increase.

5. Create the entity *Thyroid.*

6. Make the quantity *Calcitonin* of the entity *Thyroid.*

7. Read Box 3.

Box 3. A proportional relationship.

In a proportional relationship, a change in the quantity that is the cause **causes a change** in the quantity that is the effect. In DynaLearn, **positive** and **negative proportional** relationships between quantities are indicated with P+ and P− respectively.

8. The relationship between *Calcitonin* and Ca^{2+} is **proportional**. Make this relationship (see →). Pay attention to the correct direction of the arrow (cause → effect).

9. Is your screen content a bit messy? For a better organization, click on and on to make your model fit on the screen.

10. Create the entity *Blood.*

11. Make the quantity Ca^{2+} of the entity *Blood.*

12. The relationship between Ca^{2+} of the entity *Bones* and Ca^{2+} of the entity *Blood* is **proportional**. Make this connection. Pay attention to the correct direction of the arrow (cause > effect).

13. Read Box 4.

Box 4. Help function.

If the question mark ? or an ingredient in your model is red, then something is wrong. Click the question mark ? for a hint. Then click on a number, for example 1 to see where the error is in your model. Only use the question mark if you can't figure it out yourself!

14. Try out the help function by making a mistake in your model. Click ? to see which notification you get. Fix the error.

15. Read Box 5.

Box 5. An exogenous influence.

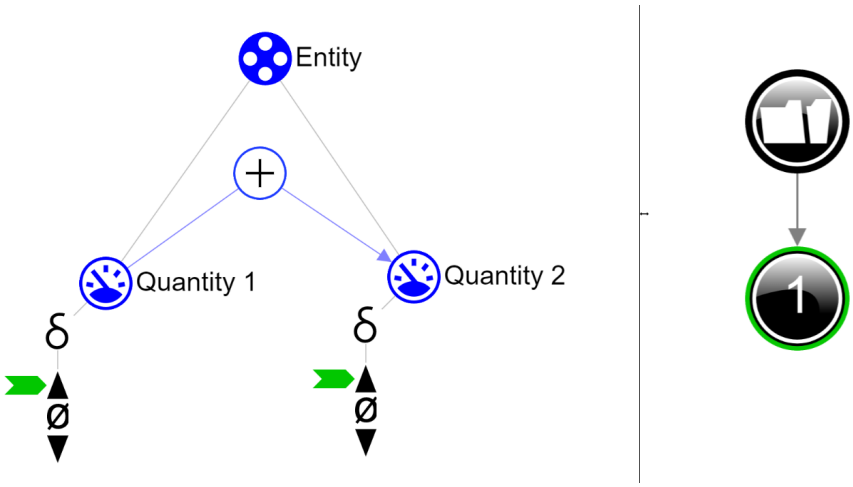
If you want a quantity to decrease, remain stable or increase throughout the simulation, you must add an external influence (an exogenous influence) to the quantity.

16. Set as initial change:
    a. Make a **rising** exogenous influence (see →) for *Calcitonin*. We have not yet defined in the model what affects the *Calcitonin*.

17. Read Box 6.

Box 6. Read the outcome of a simulation.

After starting a simulation (with), a window appears on the right in which the possible states of the system are indicated. There is one possible state in this example .



You can click on the state to view the outcome. The state icon then gets a green circle. In the model, the change for this state is indicated by green arrows . The model shows that in state *Quantity 1* increases and that therefore *Quantity 2* also increases.

18. Start the simulation (note: there are two buttons for a simulation, use the right button for a full simulation).

19. Read the simulation outcome. What happens to the amount of calcium in the bones and blood as calcitonin increases?
Also investigate what happens when calcitonin decreases. To do this, change the exogenous influence to **decreasing**. Describe below what the cause-effect relationships are that take place (cross out incorrect answers):

If calcitonin increases, the amount of Ca^{2+} in the bones will *decrease/remain the same/increase*. As a result, the quantity of Ca^{2+} in the blood will *decrease/remain the same/increase*. If calcitonin decreases, the amount of Ca^{2+} in the bones will *decrease/remain the same/increase*. As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase*.

4. PTH and Ca^{2+} in bones and blood

The model is now extended to make the connection between PTH and the amount of Ca^{2+} in the bones and blood (see Figure 1).

1. Create the entity *Parathyroid*.
2. Create a configuration *has* between the entity *Thyroid* and *Parathyroid* (see →).
3. Create the quantity *PTH* of the entity *Parathyroid*.
4. The relationship between *PTH* of the entity *Parathyroid* and *Ca^{2+}* of the entity *Bones* is **proportional**. Make this relationship. Pay attention to the right direction of the arrow (cause → effect).
5. Set as initial change:
   a. Change the exogenous influence (see →) for *Calcitonin* to **constant**.
   b. Create an **increasing** exogenous influence for *PTH.*
6. Start the simulation .
7. Read the simulation outcome. What happens to the amount of calcium in the bones and blood as PTH **increases**? Also investigate what happens when PTH **decreases**. To do this, change the exogenous influence to **decreasing**. Describe below what the cause-effect relationships are that take place (cross out incorrect answers):

If PTH increases (and calcitonin is constant) then the amount of Ca^{2+} in the bones will *decrease/remain the same/increase*. As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase*. If PTH decreases (and calcitonin is constant) then the amount of Ca^{2+} in the bones will *decrease/remain the same/increase*. As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase*.

5. Difference from a norm

The production of calcitonin and PTH is determined by a **norm**. If the amount of Ca^{2+} in the blood is **greater** than the **norm**, than **more calcitonin** will be produced than **broken down** and **less PTH** will be produced than **broken down**. If the amount of Ca^{2+} in the blood is less than the norm, the opposite effect applies.

1. Make the quantity *Difference* of the entity *Thyroid* entity. This quantity indicates whether the amount of Ca^{2+} in the blood differs from the **norm**.

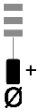
2. Read Box 7.

Box 7. Quantity Space.

A newly created quantity does not yet have a quantity space. By adding a quantity space, you can indicate which values a quantity can take. A quantity space consists of points (●) and intervals (▮).

- A *point value* is only one value. For example, a *boiling point*. A special point is the zero point, for which there is a separate symbol (Ø) in DynaLearn.
- An *interval* is a set of values. The liquid phase of a substance is an example of an interval. In the case of water, the interval 'liquid' contains all values between 0 °C and 100 °C. The values 0 °C and 100 °C are respectively the 'melting *point*' and the 'boiling *point*' between which the interval 'liquid' is located.

3. Create a quantity space (see →) for the quantity *Difference* with a zero point (Ø) and an interval (+) above it. If the difference is positive (+) then the norm is exceeded. It will look like this:



4. Read Box 8.

Box 8. An influence relationship.

Some quantities in a system are processes. A process is a quantity that adds or removes something to the system per unit of time (e.g. per second, per year). Simple examples of processes that **add** something are: (i) water from a tap that flows (L/s) into a bath and (ii) an oven that provides a certain power (J/s) to heat a dish. (iii) the amount of tax paid every year (€/y). The outflow (L/s) of water through the drain is an example of a process that removes something from the system.

The connection between a process and another quantity is called an **influence** in DynaLearn (I+ or I−). In this type of relationship, the **value** of the process determines the **change** in the quantity on which an influence is exerted.

5. The relationship between *Difference* and the **two** *Thyroid* hormones is of the type of **influence**. The difference determines the speed of a process (release of a hormone per **unit of** time vs. the breakdown **per unit of time**). Make these two relationships (→). Pay attention to the correct direction of the arrows (cause → effect).

6. Did you made use of the function aligning and fit the screen ?

7. Set as initial value and initial change (see →):
   a. Remove the exogenous influence in *Calcitonin* and *PTH.*
   b. *Difference* is positive (+). This is the **value** of *Difference*.
   c. Create an exogenous influence for *Difference* of type **equal** (=constant). This is the **change** of *Difference*.

8. Read Box 9.

Box 6. Help function

If the explanation mark appears , something is wrong during the simulation. Click on the explanation mark for a hint. Then click on a number, for example 1, to see where the error is in your simulation.

9. Start the simulation . Read the simulation outcome and answer the question below (cross out incorrect answers):

If the difference (with the norm) is positive (= the value) and constant (= the change) then the amount of calcitonin will *decrease/remain the same/increase* and the amount of PTH will *decrease/remain the same/increase*.

10. The amount of Ca^{2+} in the blood can also be less than the norm. The difference is then negative. Create a negative value (-) at the quantity space of the quantity *Difference.* So, you place this value below zero (Ø).

11. Set as initial value (see →):
   a. *Difference* is negative. So put a near the **value** (-).
   b. The exogenous influence on *Difference* remains constant.

12. Start the simulation. Read the simulation outcome. What happens to *Calcitonin* and *PTH* if the *Difference* (with the norm) is **negative** and **constant**?

If the difference (with the norm) is negative (= the value) and constant (= the change) then the amount of calcitonin will decrease/remain the same/increase and the amount of PTH *decrease/remain the same/increase*.

6. Feedback on difference

A change in the **amount of** Ca 2+ in the blood has an **effect on** the difference compared to the norm. If there is a positive difference with the norm, more Ca 2+ will be absorbed into the bones, so that there is less Ca^{2+} in the blood . The difference compared to the standard will then decrease. Thus, there is negative **feedback** (see Figure 1).

1. Make the connection between *Ca^{2+}* of the entity *Blood* and *Difference.*

2. Set as initial value:
   a. *Difference* is positive (+). So put a  near the **value** (+).
   b. Remove the exogenous influence on *Difference*.

3. Start the simulation . Read the simulation outcome and answer the question below (cross out incorrect answers):

State 1: The difference (with the norm) is positive. The amount of calcitonin will *decrease/remain the same/increase*. The amount of Ca^{2+} in the bones will *decrease/remain the same/increase.* As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase.* The difference (with the norm) will *decrease/remain the same/increase*.

State 2: The difference (with the norm) is *negative/zero/positive*. The amount of calcitonin will *decrease/remain the same/increase*. The amount of Ca^{2+} in the bones will *decrease/remain the same/increase.* As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase*. The difference (with the norm) will *decrease/remain the same/increase*.

7. The norm

You are now going to include the norm in the model. The difference can then be **calculated** by the deviation of Ca^{2+} in the blood compared to the norm.

1. Make the quantity *Norm* of the entity *Thyroid.*

2. Create a quantity space for quantity Norm with an interval called *Norm*. It will look like this:

3. Create a quantity space for the quantity *Ca^{2+}* of *Blood* with an interval (+).

4. Read Box 10.

Box 10. A calculus

Sometimes a quantity is the **sum of** or the **difference** between two other quantities. You can also display this in your model. For example: income - expenses = profit.
With the minus sum (-) or plus sum (+) you can indicate how the two quantities lead to an outcome of a third quantity, you do this by using the equal sign (=) afterwards.

5. Make the calculus (see →): Ca^{2+} in *Blood – Norm = Difference*

6. Read Box 11.

Box 11. An (in)equality

An inequality (<, ≤, ≥, >) can indicate which values of two quantities are initially the largest (e.g. A < B). You can also indicate that both values are initially equal (=) with an equality.
Note! This concerns the **initial** (in)equality, i.e. at the beginning of the simulation. This can change over the course of the process.

7. Set as initial value:
   a. Remove the initial value *Difference* (remove at +).
   b. Create an (in)equality (see →): *Ca^{2+}* of *Blood* **<** *Norm.*
   c. Create an exogenous influence that is **constant** for *Norm*.
   d. Put a near the value (+) *Ca^{2+}* of *Blood***.**
   e. Put a near the value *Norm* of the quantity *Norm*.

8. Start the simulation . Read the simulation outcome and answer the question below (cross out incorrect answers):

State 1: The difference (with the norm) is negative. The amount of calcitonin will *decrease/remain the same/increase*. The amount of Ca^{2+} in the bones will *decrease/remain the same/increase*. As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase*. The difference (with the norm) will *decrease/remain the same/increase*.

State 2: The difference (with the norm) is *negative/zero/positive*. The amount of calcitonin will *decrease/remain the same/increase*. The amount of Ca^{2+} in the bones will *decrease/remain the same/increase*. As a result, the amount of Ca^{2+} in the blood will *decrease/remain the same/increase*. The difference (with the norm) will *decrease/remain the same/increase*.

8. Resorption of Ca^{2+} by the kidneys

The model is now extended to include the relationship between calcitonin and PTH and the resorption of Ca^{2+} by the kidneys (see Figure 1).

1. Create the entity *Kidney*.

2. Create the quantity *Resorption Ca^{2+}* of the entity *Kidney.*

3. There are **two** quantities that have an effect on *Resorption Ca^{2+}*. Make these two relations.

4. The quantity *Resorption Ca^{2+}* has an effect on the amount of *Ca^{2+}* in the blood. Make this relation.

5. Set as initial value:
   a. Leave it as it is from previous simulation.
   b. Note! The equality sign should indicate: *Ca^{2+}* of *Blood* **<** *Norm.*

6. Start the simulation. Read the simulation outcome and answer the question below (cross out incorrect answers):

State 1: The amount of Ca^{2+} in the blood is *less than/equal to/greater than* the norm. The amount of calcitonin decreases and the amount of PTH increases. As a result, the resorption of Ca^{2+} by the kidneys will *decrease/remain the same/increase*.

State 2: The amount of Ca^{2+} in the blood is *less than/equal to/greater than* the norm. As a result, the resorption of Ca^{2+} by the kidneys will *decrease/remain the same/increase*.

9. Resorption of Ca^{2+} by the intestines

The model is now extended to include the link between calcitonin and PTH and the uptake of Ca^{2+} by the intestines (see Figure 1).

1. Create the entity *Intestines*.

2. Create the quantity *Resorption Ca^{2+}* of the entity *Intestines*.

3. There are **two** quantities that have an effect on the *Resorption Ca^{2+}*. Make these two relations.

4. The quantity *Resorption Ca^{2+}* has an effect on the amount of *Ca^{2+}* in the blood. Make this relation.

5. Set as initial value:
   a. Leave it as it is from previous simulation.

6. Start the simulation. Read the simulation outcome and answer the question below (cross out incorrect answers):

State 1: The amount of calcitonin decreases and the amount of PTH increases. As a result, the absorption of Ca^{2+} by the intestines will *decrease/remain the same/increase*.

State 2: The amount of calcitonin and PTH is constant. As a result, the absorption of Ca^{2+} by the intestines will *decrease/remain the same/increase*.

10. Sunlight, Vitamin D and resorption of Ca2+ by the intestines

Rickets or English disease is a bone disorder caused by a lack of vitamin D and calcium. The disease occurs especially in children in early childhood. Sufficient exposure to sunlight prevents rickets by producing sufficient vitamin D. In the past, a sunlamp was sometimes used as a treatment against the disease. In countries where vitamin D is added to margarine or milk, rickets is virtually non-existent.

1. Create the entity *Skin*.
2. Create the quantity *Sunlight* of the entity *Skin.*
3. Make the quantity *Vitamin D* of the entity *Skin.*
4. The quantity *Sunlight* has an effect on the amount of *Vitamin D*. Make this relationship.
5. The quantity *Vitamin D* has an effect on *Absorption* Ca^{2+} by the intestines. Make this relationship.
6. Set as initial value:
   a. Change the (in)equality to: Ca^{2+} of *Blood* **=** *Norm* (click on the inequality to adjust it).
   b. Create an exogenous influence that **decreases** for *Sunlight*.
7. Start the simulation. Read the simulation outcome:

State 1 and 2: The amount of sunlight on the skin decreases. As a result, the amount of Vitamin D made by the skin will *decrease/remain the same/increase*. As a result, the absorption of Ca^{2+} by the intestines will *decrease/remain the same/increase*. The amount of Ca^{2+} in the blood will decrease and will therefore be *less than/equal to/greater than* the norm. The amount of Ca^{2+} in the bones will *decrease/remain the same/increase*.