

# Calcium homeostasis

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

DynaLearn level 4

<b>Summary</b>	
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.	
<b>Given name</b>	
<b>Surname</b>	
<b>Class</b>	
<b>Date</b>	
<b>Comments by teacher</b>	

# 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.

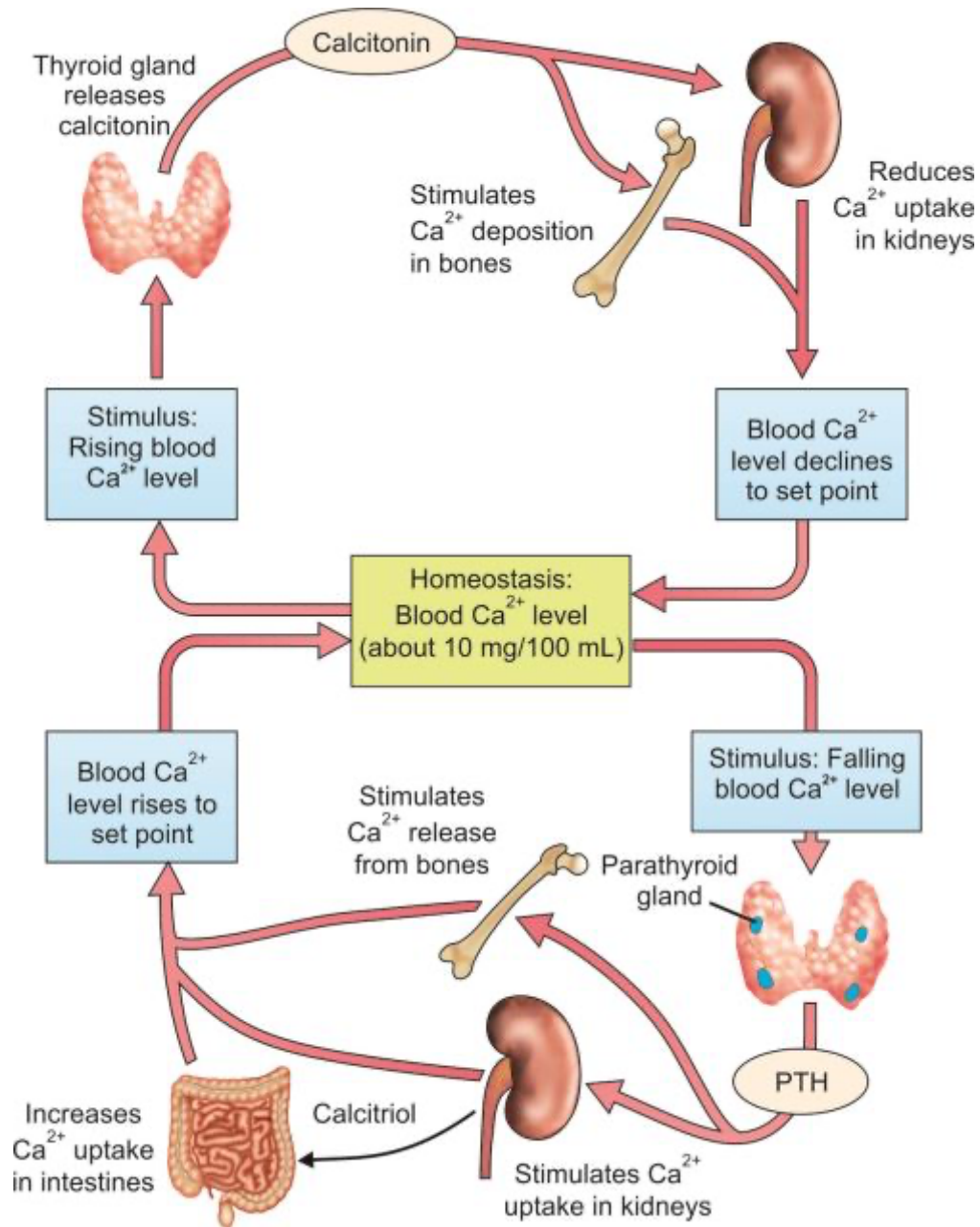


Figure 1. The calcium balance of a person

## 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 . The delta symbol ( $\delta$ ) is the mathematical sign for change (also called the derivative). The down arrow () is a decrease, the zero ( $\emptyset$ ) 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  and  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  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.

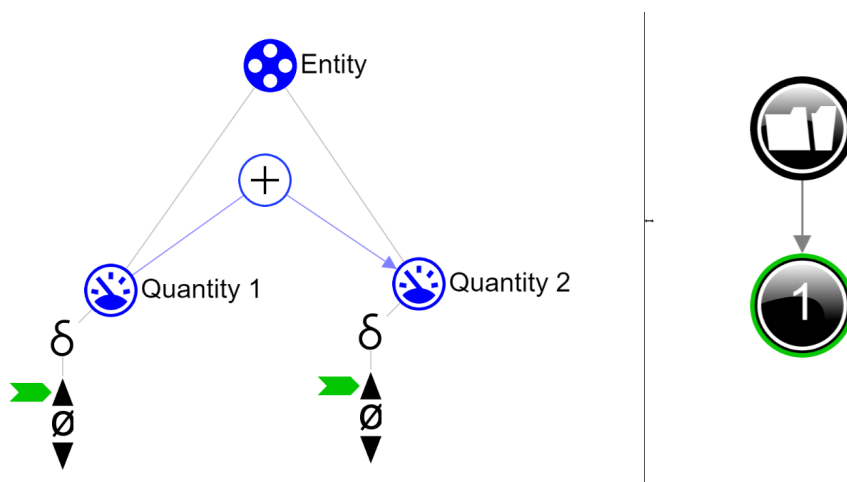
16. Set as initial change:



- 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 $\text{Ca}^{2+}$ in bones and blood

The model is now extended to make the connection between PTH and the amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*. As a result, the amount of  $\text{Ca}^{2+}$  in the blood will *decrease/remain the same/increase*.




If PTH decreases (and calcitonin is constant) then the amount of  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*. As a result, the amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the blood is less than the norm, the opposite effect applies.

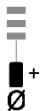
1. **Make** the quantity *Difference* of the entity *Thyroid* entity. This quantity indicates whether the amount of  $\text{Ca}^{2+}$  in the blood differs from the **norm**.
2. **Read** Box 7.

### Box 7. Value range.

A newly created quantity  does not yet have a value range. By adding a value range, you can indicate which values a quantity can take. A value range 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 ( $\emptyset$ ) 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 value range (see  → ) for the quantity *Difference* with a zero point ( $\emptyset$ ) 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 in Dynalearn an **influence** ( or ). 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  → ):
- Remove** the exogenous influence in *Calcitonin* and *PTH*.
  - Difference* is positive (+). This is the   $\emptyset$  **value** of *Difference*.
  - 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 , 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  $\text{Ca}^{2+}$  in the blood can also be less than the norm. The difference is then negative. **Create** a negative value (-) at the value range of the quantity *Difference*. So, you place this value below zero ( $\emptyset$ ).
11. **Set** as initial value (see  → ):
- Difference* is negative. So **put** a  near the **value** (-).
  - 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**  $\text{Ca}^{2+}$  in the blood has an **effect on** the difference compared to the norm. If there is a positive difference with the norm, more  $\text{Ca}^{2+}$  will be absorbed into the bones, so that there is less  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*. As a result, the amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*. As a result, the amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the blood compared to the norm.

1. **Make** the quantity *Norm* of the entity *Thyroid*.
2. **Create** a value range for the quantity *Norm* with an interval called *Norm*. It will look like this:



3. **Create** a value range for the quantity  $\text{Ca}^{2+}$  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  → ):  $\text{Ca}^{2+}$  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  → ):  $\text{Ca}^{2+}$  of *Blood* < *Norm*.
  - c. **Create** an exogenous influence that is **constant** for *Norm*.
  - d. **Put** a  near the value (+)  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*. As a result, the amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*. As a result, the amount of  $\text{Ca}^{2+}$  in the blood will *decrease/remain the same/increase*. The difference (with the norm) will *decrease/remain the same/increase*.

## 8. Resorption of $\text{Ca}^{2+}$ by the kidneys

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

1. Click on , select , 'Calcium homeostasis – extended' and click on .
2. Create the entity *Kidney*.
3. Create the quantity *Resorption  $\text{Ca}^{2+}$*  of the entity *Kidney*.
4. There are **two** quantities that have an effect on *Resorption  $\text{Ca}^{2+}$* . Make these two relations.
5. The quantity *Resorption  $\text{Ca}^{2+}$*  has an effect on the amount of  $\text{Ca}^{2+}$  in the blood. Make this relation.
6. Set as initial value:
  - a. Leave it as it is from previous simulation.
  - b. Note! The equality sign should indicate:  $\text{Ca}^{2+}$  of *Blood* < *Norm*.
7. Start the simulation. Read the simulation outcome and answer the question below (cross out incorrect answers):

State 1: The amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  by the kidneys will *decrease/remain the same/increase*.

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

## 9. Resorption of $\text{Ca}^{2+}$ by the intestines

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

1. **Create** the entity *Intestines*.
2. **Create** the quantity *Resorption  $\text{Ca}^{2+}$*  of the entity *Intestines*.
3. There are **two** quantities that have an effect on the *Resorption  $\text{Ca}^{2+}$* . **Make** these two relations.
4. The quantity *Resorption  $\text{Ca}^{2+}$*  has an effect on the amount of  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  by the intestines will *decrease/remain the same/increase*.

## 10. Sunlight, Vitamin D and resorption of $\text{Ca}^{2+}$ 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  $\text{Ca}^{2+}$*  by the intestines. **Make** this relationship.
6. **Set** as initial value:
  - a. **Change** the (in)equality to:  *$\text{Ca}^{2+}$  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  $\text{Ca}^{2+}$  by the intestines will *decrease/remain the same/increase*. The amount of  $\text{Ca}^{2+}$  in the blood will decrease and will therefore be *less than/equal to/greater than* the norm. The amount of  $\text{Ca}^{2+}$  in the bones will *decrease/remain the same/increase*.