PHYSIOLOGY

1

Lec: 2

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PHYSIOLOGY LECTURE 2

CONTROL SYSTEMS OF THE BODY

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Lecture Objectives:

- Define and describe the components of homeostatic control system.
- List the factors that are homeostatically regulated.
- Compare and contrast negative and positive feedback and explain the importance of these processes to homeostasis.
- Understand the gain of the control system and its physiological significance.
- Explain the feed forward concept and its importance for initiation of responses in anticipation of a change in internal environment.

Factors homeostatically regulated:

Factors of the internal environment that must be homeostatically maintained are:

1. Concentration of nutrient molecules.
2. Concentration of oxygen and carbon dioxide.
3. Concentration of waste products.
4. pH (hydrogen ion concentration).
5. Water volume and osmolality (essential electrolyte concentrations).
6. Plasma volume and pressure.
7. Core body temperature.

examples:

1- maintain a certain level of glucose concentration, this also applies for amino acids and fatty acids

2- maintain a constant percentage of O_2 and CO_2 levels

3- waste products such as (creatinine and urea) should not increase beyond a certain level

V.V.V. impt

4 - ph (the concentration of the H^+ ion) is one of the most important indicators (من أهم المؤشرات) cuz every enzyme works in a specific pH range, so, if the pH level isn't constant and always changing the enzymes in the body will stop working, which may contribute (يؤدي) to death.

5 - having a constant percentage of Na^+, Ca^{2+} K^+, and a specific water and blood volumes in the body

6- The amount of blood that runs through blood vessels (not all the liquids only the blood (Plasma)).
Blood pressure should also be constant at a specific number (usually 120/80) no more or less

7- Core body temperature, Core: the internal temp. of the body, and not the temp. on the surface of the skin, cuz the skin is affected by the outside environment (if the weather is cold your skin is cold).
so, core body temp = the internal temp. of the blood in the body (usually 37.5)

أما الأمور الأخرى ليس بالضرورة ان تكون ثابتة، هاي هي الاهداف الي الجسم بده يحافظ عليها، لكن حتى تحافظ عليها هناك وسائل فالوسيلة تتغير، و هون بتصير الخربطة عند الطلاب،
مثال: هل من ضمن هذه العوامل كم مرة نتنفس بالدقيقة؟ و هل كمية النفس لازم تكون ثابتة و ما تتغير؟ لا ممكن تزيد أو تنقص، لان هي وسيلة للتصحيح

مثال آخر: إذا الأكسجين في الجسم قل، الجسم رح يزيد معدل التنفس (hyper ventilation) هل هذا يعني انه هاي (abnormality) ؟ و هل لازم تنزل سرعة النفس إلى رقم ثابت؟ لا، لان هذه وسيلة و الوسيلة تتغير، لتحقيق هدف، و منه نستنتج ان الهدف هو من يبقى ثابتا و ليس الوسيلة

Control systems of the body

- Control systems of the body are in thousands. Starting from the cellular level and ending in throughout the entire body control systems.
- To maintain homeostasis, the control system must be able to:

1) Detect deviations from normal in the internal environmental factor that needs to be held within narrow limits.
2) Integrate this information with any other relevant information.
3) Make appropriate adjustments in the activity of the body parts responsible for restoring this factor to its desired value

- Examples are Na^+-K^+ pump, genetic control, pH regulation, and thermal regulation of the body.
- Homeostatic regulation of a single physiologic factor often involves several cooperating control systems (mechanisms) activated at the same time or in succession.

- control system : any sestem that corrects an error
- to maintain homeostasis the control systems must be able to :

control systems

Detect

- There should be a way to figure out or to know if something is wrong

Integrate

- Cooperate (يتعاون) with the other control systems in the body
- the control systems gather all the information and work together to fix the issue

Adjustments

- the ability of making a change or correcting an error

ex: Na - K pump , Kicks out Na^+ and Lets K^+ enter the cell

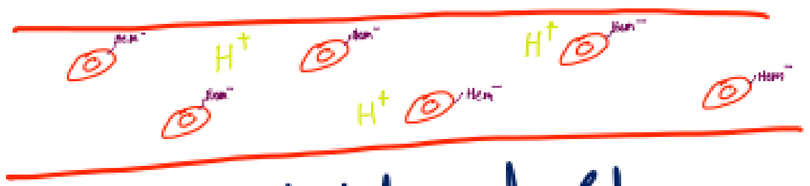
- pH regulatio (تركيز) ex: the concentration of H^+ ions in the blood has increased, what will happen?

the first control system will begin to work (Hemoglobin) the hemoglobin carries a negative charge and the H^+ ion is positively charged. the Hemoglobin is located on the red blood cells, which swim in the blood stream. so, if the Level of the H^+ ion starts to increase, the hemoglobin

in the blood will begin to attach with it, to lower the number of H^+ ions in the body.

رسم توضيحي

(1)



normal blood flow

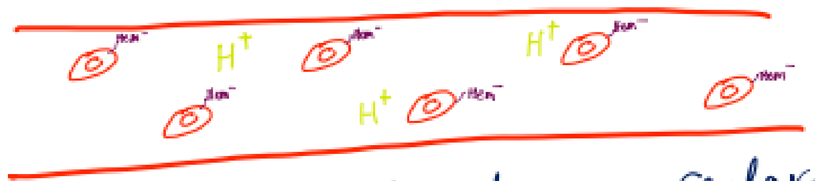
(2)

the pH level in the blood starts to increase

(3)

Hemoglobin attaches the H^+ ions and begins to lower the PH level in the blood

(4)



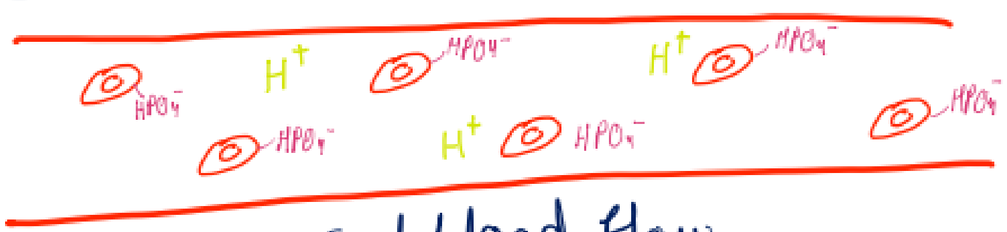
normal PH levels are restored in the body

the second control system: in the cell. there is a compound (مركب) called phosphate, (PO_4^{-2}) in the cell it is found as (HPO_4^-), so when the H^+ ions increase, it attaches to the (HPO_4^-) and become (H_2PO_4), so it cancels out the charges and becomes nutral (متعادل)

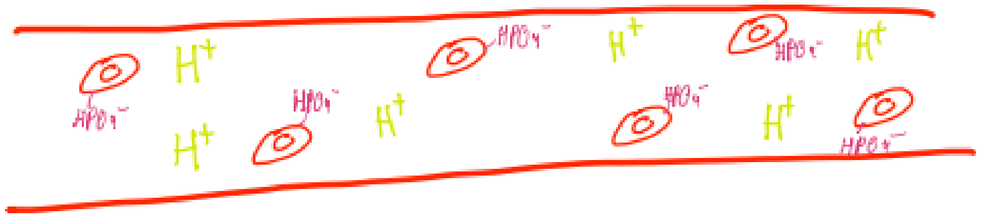
رسم توضيحي

(2)

(1)

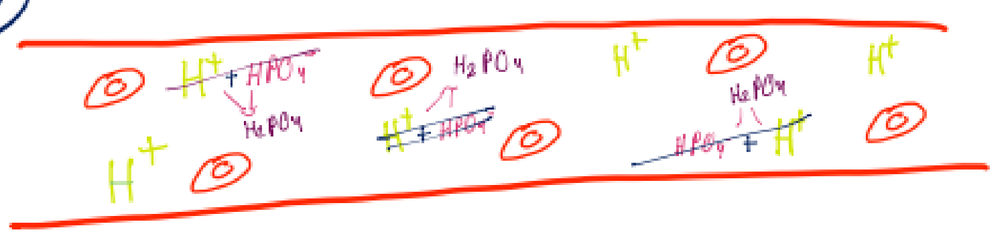


normal blood flow

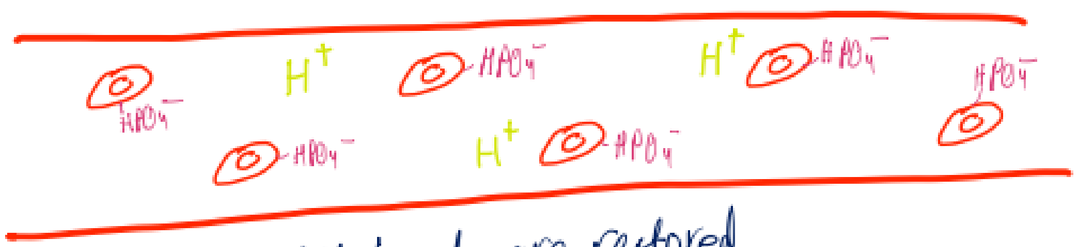


the pH level in the blood starts to increase

(3)



phosphate attaches the H^+ ions and begins to lower the PH level in the blood



normal PH levels are restored in the body

— the third control system: the lungs senses the increase in the pH levels, so it will increase the breathing rate.
(the person with high acidity in the blood has a condition called acidotic Breathing (تنفس حامضي) it appears as the person was exercising, however the patient is sitting down and didn't exercise, this is an indicator of acidotic Breathing)
the lungs Breath out CO_2, the more CO_2 is out of the body the less the H^+ ions are in the blood stream

— The fourth control system: The urine is acidic (PH = 6), The Kidneys have the ability to remove H^+ ions from the body and into the urine, so if we have an increase in H^+ ion the Kidney will increase the acidity of the urine

Control systems of the body (Cont.)

- The more important a variable, the more numerous and complicated are the mechanisms that operate to maintain the steady-state at the desired value.
- The efficiency of the homeostatic mechanisms varies over a person's lifetime, with some homeostatic mechanisms not being fully developed at birth and others declining with age.
- For example, a newborn infant cannot concentrate urine as an adult. Older adults are less able to tolerate stresses, such as exercise or changing weather, than are younger adults.
- The control systems are characterized by their:
  1. *Negative feedback nature (the majority)*
  2. *Positive feedback nature*

what stress? some may Identify it as constant anxiety. However, in physiology "stress" means any external or internal condition that challenges homeostasis, and it can be several things

examples of stress:

- decrease in glucose levels (hypo glycemia)
- -- in oxygen levels (مثال الحريق)
- getting cold
- A broken arm or leg and feeling the pain
- hypovelemia (decrease in the volume of the blood)

* younger adults or youth can withstand (يتحمل) cold temps more than adults

* the sense of smell is stronger in young kids rather than adults

* women have higher pitched sounds than men because the frequency is higher, when men get older their hearing ability to womans voice gets weaker

Negative feedback: (95% - 98%)

When some factors becomes excessive or deficient, series of changes occur that move the factor in the opposite direction of its initial change. That is, a corrective adjustment opposes the original deviation from the homeostatic steady-state.

The components of a simple negative-feedback control system include:

- Regulated variable
- The receptor (sensor or detector)
- The control center (comparator or integrator)
- The effector (acts to oppose change)

Example: Exercise → ↑ body temperature → stimulation of temperature-monitoring nerve cells in the hypothalamus → activation of cooling mechanisms (sweating) → ↓ body temperature.

- activation of cooling mechanisms (Breathing):

The lungs will increase the breathing rates and you will start panting (out), so, hot air will come out and take in cold air which goes into the lungs and comes out hot again this will help you lose heat and cool down. also the hot air that you exhale will evaporate the water on the trachea and its branches, this will cool you down

Gain of a Control System:

- The gain is degree of effectiveness with which a control system maintains constant conditions.
- The gain of the control system is calculated by the following formula:

$$The\ \mathbf{Gain}\ of\ a\ control\ system = \frac{Correction}{Error}$$

Where the *Error* is the remaining uncorrected change from normality. The gain of baroreceptors is about -2, whereas the gain of temperature control system is about -33.

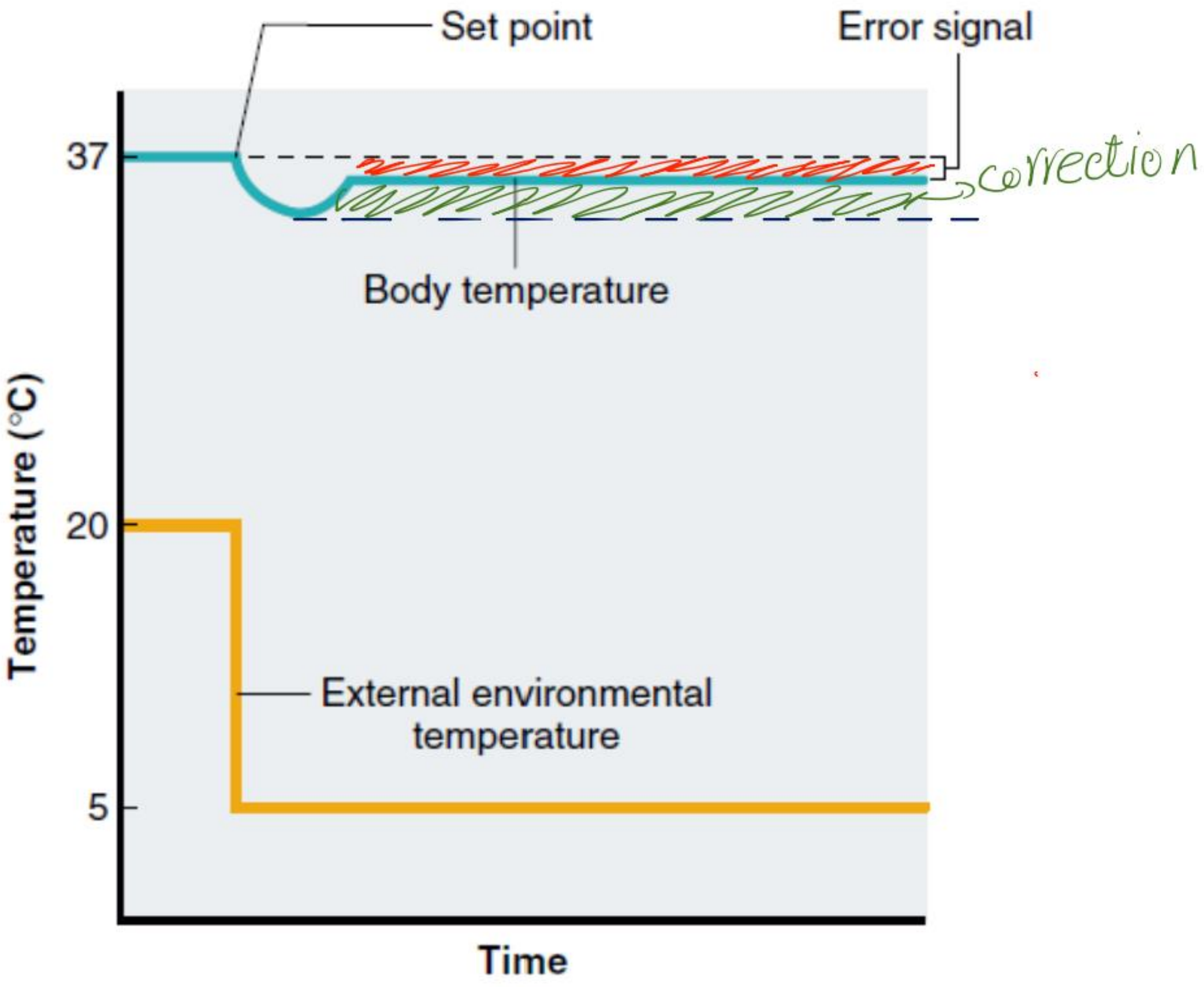
there is no control system that is 100% efficient, but it corrects it as close to original as possible

ex: the blood pressure was 100, then a bleed happened and it is down to 80 now, the C.S started working and raised the BP to 95, so there is still "5" error and "15" correction

so Gain $= \frac{+15}{-3} = -3$, Gain is always negative

السالب دلالة على الإتجاه

*the higher the value the better the effectiveness


Set point
Error signal
37
correction
Body temperature
Temperature (°C)
20
External environmental
temperature
5
Time

Feedforward Regulation:

- Is another type of regulatory process usually acts in combination with negative-feedback systems
- The feedforward regulation **anticipates** changes in a regulated variable, improves the speed of the body's homeostatic responses, and minimizes fluctuations in the level of the variable being regulated - that is, it reduces the amount of deviation from the set point

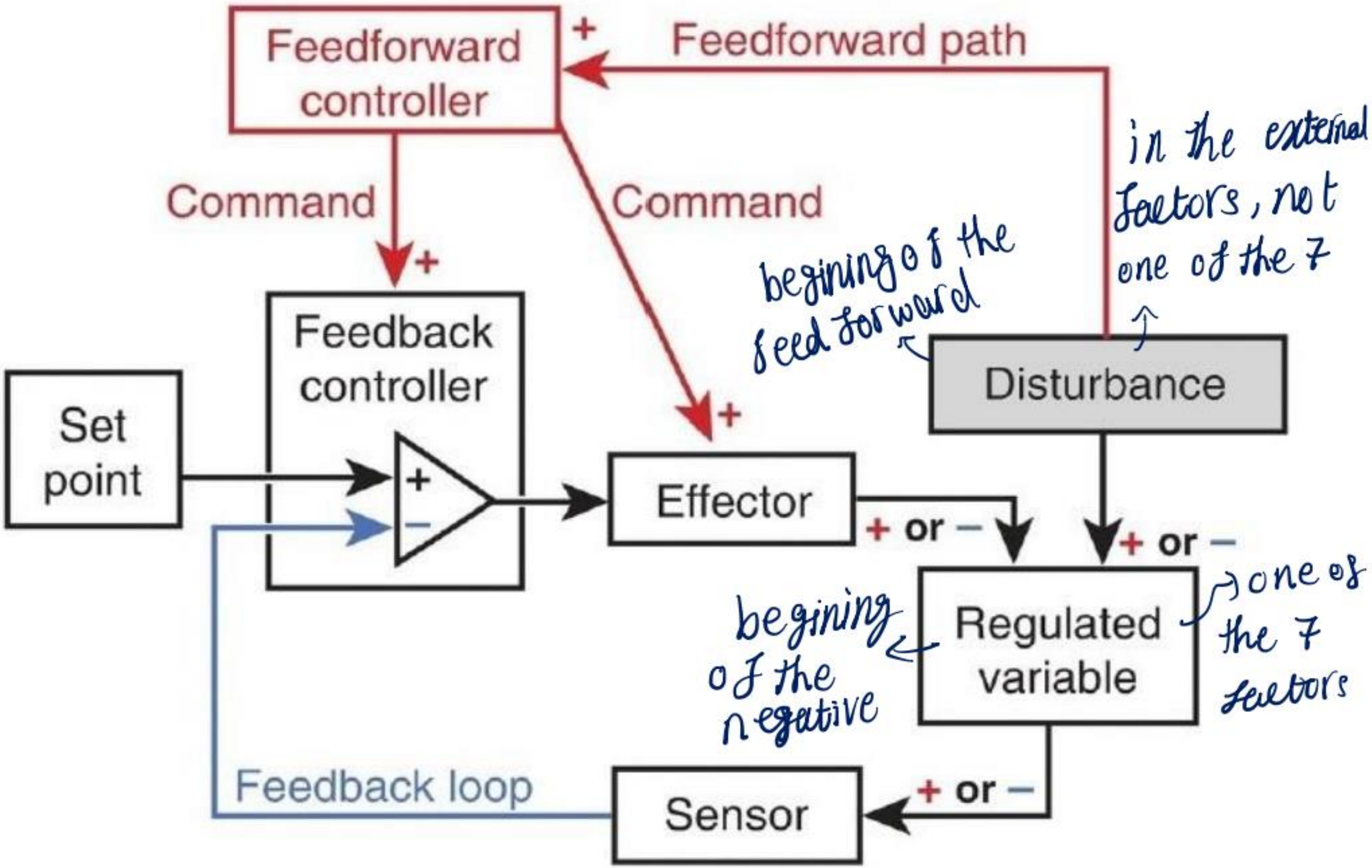
before it happens

- The operation of the controller is "**open loop**"; that is, the regulated variable itself is not sensed
- ***Example***; When outside temperature falls, skin nerve cells immediately detect the change and relay this information to the brain, which then sends out signals to the blood vessels and muscles, resulting in heat conservation and increased heat production even before the internal body temperature falls

another example: you are walking and you step in a hole in the ground, the body will anticipate the fall and your leg muscles will contract and help you keep your balance

another example: when the mother is breast feeding its infant, she might feel that the kid is starting to urinate (يتبول) or even defecate (تبرز) as if the stomach is telling the colon to empty up and make space for the new food or milk

another ex: you ate food, and it went down to the intestines and got absorbed into the bloodstream, the pancreas (the organ responsible for secreting (يفرز) insulin) has his own blood vessels, beta-cells feel the rate of sugar (glucose) in the blood, when it feels that the rate is high, the pancreas starts making insulin, however the pancrease started secreting insulin before the food even got swallowed, it anticipated that the food will get down to the stomach, so there is no need to wait for it and the glucose rate will skyrocket (600); so even if it increased it will only get up to (150-200)


Feedforward controller
+
Feedforward path
Command
+
Command
+
Feedback controller
Set point
+
−
Effector
+ or −
+ or −
Disturbance
Regulated variable
+ or −
Sensor
Feedback loop
beginning of the feed forward
in the external factors, not one of the 7
beginning of the negative
one of the 7 factors

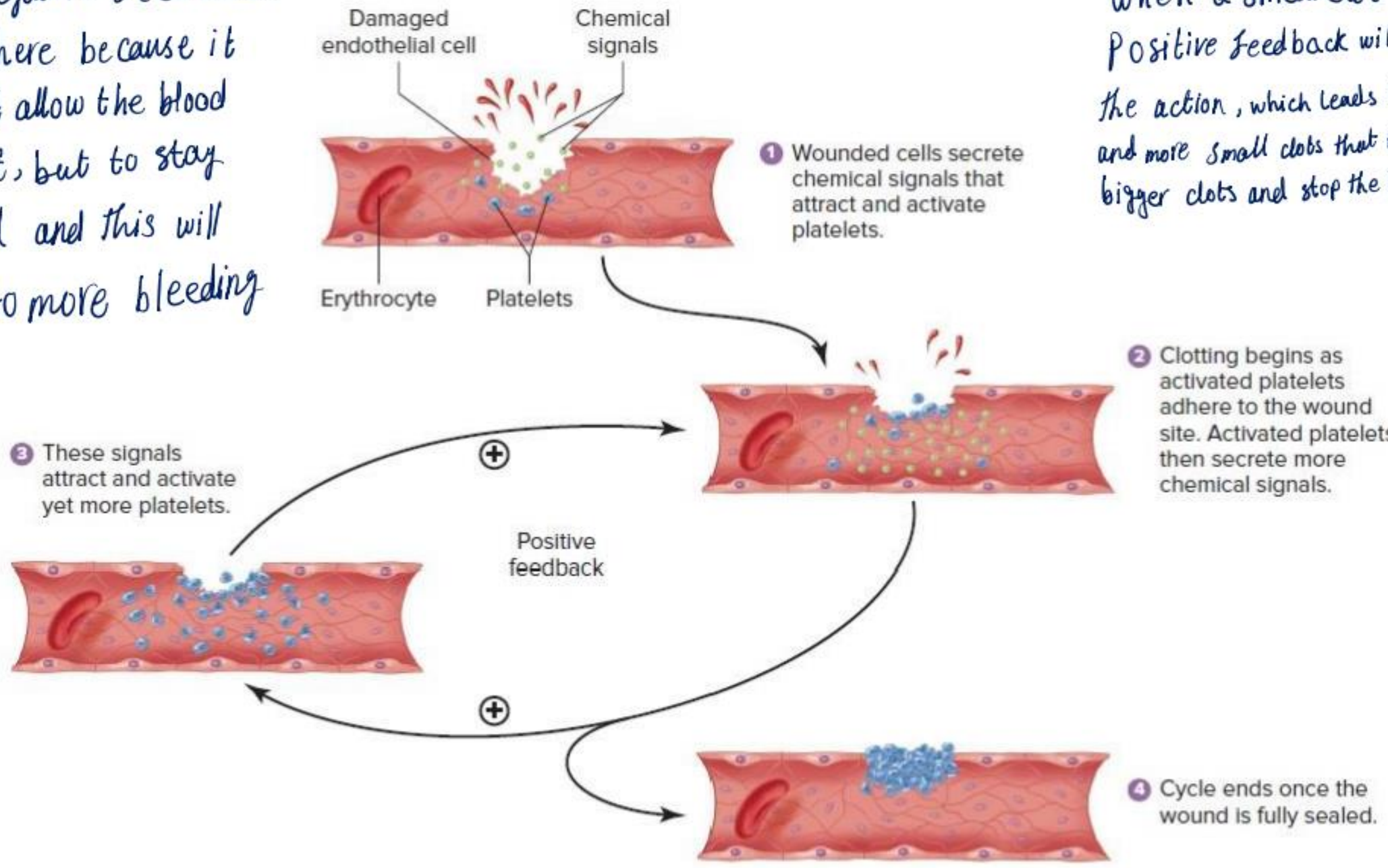
Positive feedback:

going down hill

- The change induces further change leading to an amplified effect that ends in **vicious cycle**. It can be useful in some cases; e.g. blood clotting, childbirth (initiation of uterine contraction), generation of action potential in membrane of nerve cell when Na^+ ion influx begins, ovarian ovulation, etc.
- The positive feedback may be considered as a part of an overall negative feedback process.
- **Example:** blood clotting, the positive feedback clotting process is a negative feedback process for the maintenance of normal blood volume.

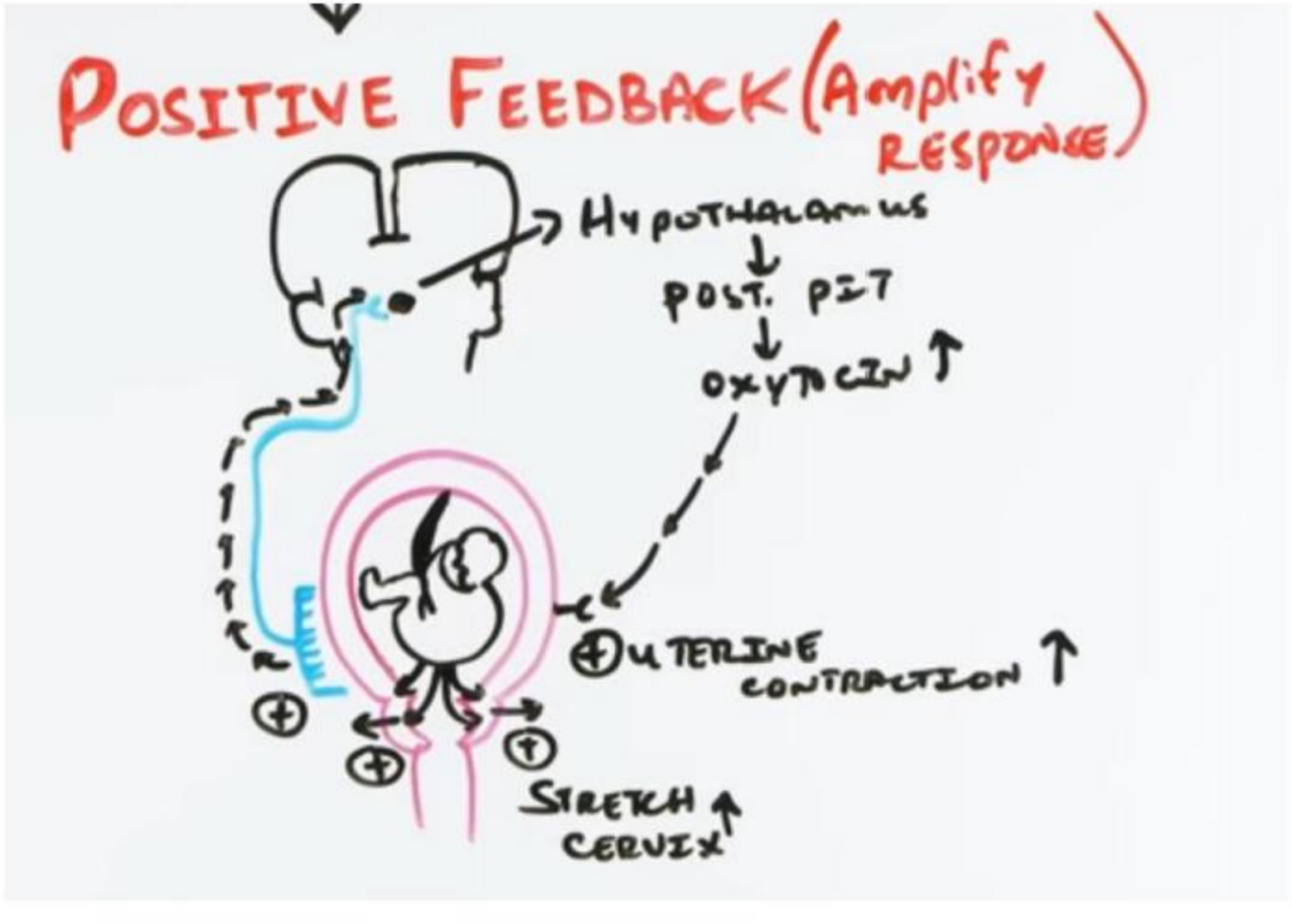
the negative feedback fails here because it doesn't allow the blood to clot, but to stay liquid and this will lead to more bleeding

when a small clot forms Positive feedback will amplify the action, which leads to more and more small clots that turn into bigger clots and stop the bleeding



Positive feedback as illustrated by the clotting process in blood. Damaged endothelial cells in the lining of a blood vessel secrete chemical signals that attract and activate platelets. As clotting begins, the activated platelets produce chemical signals of their own, attracting and activating **more** platelets to the wound site, which then produce yet **more** chemical signals, and so on. The cycle ends when the wound is fully sealed.

لما يكون الجنين في بطن الأم، يكون الرأس للاسفل و الأرجل للأعلى، و الرحم شكله كمثري، و عنق الرحم يشبه الحلقة و الرأس متمركز عند هذه الحلقة، عندما يصبح حجم الرأس كامل، يعطي إشارة لامه انه بدي يطلع، وزن الرأس و حجمه يكبس على الحلقة، و منه حجم الحلقة يتوسع، الله عز و جل خلق اعصاب في هذه الحلقة تحس بالتمدد، عندما تحس الأعصاب بقرب خروج الجنين، تعطي إشارة إلى (hypothalamus) و على (pituitary gland) هذه الإشارة التي تصعد تؤدي إلى إفراز هرمون ال (oxytocin) و وظيفة هذا الهرمون، يؤدي إلى تقلص الرحم، الرأس نزل و الحلقة توسعت و طلعت إشارة، الفرز هرمون، الهرمون اجا مع الدم، وصل للرحم و عمل تقلص للرحم، و منه يدفع الطفل للأسفل اكثر، عنق الرحم يتوسع اكثر و يعطي إشارة أقوى و يفرز (oxytocin) اكثر و تظل العملية إلى ان تتم الولادة



صورة توضيحية من متناة (ninja nerd)

Test Question:

Q. Which statement about feedback control systems is incorrect?

✓ A. Most control systems of the body act by negative feedback.

✗ B. Positive feedback usually promotes stability in a system. it promotes unstability (Amplifying)

✓ C. Generation of nerve actions potentials involves positive feedback.

✓ D. Feed-forward control is important in regulating muscle activity.

✓ E. A feedback gain of -3.0 can correct 3/4 of the initial error.

$$\frac{\frac{3}{4}}{-\frac{1}{4}} \Rightarrow \frac{3 \times \cancel{4}}{-\cancel{4}} = -3 \checkmark$$