



**HKU
Med**

LKS Faculty of Medicine
School of Biomedical Sciences
香港大學生物醫學學院

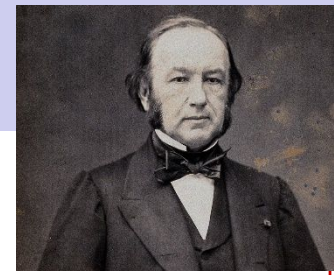
Homeostasis & Concept of Control System

Its importance and the principle of feedback mechanism

Enrichment Course in Biology

Dr Denny CW Ma

Body Compartments



Claude Bernard (1813-1878) – French physiologist

Introduced the notion that man exists in 2 environments

1. External environment

- Always changing*
- Often hostile*

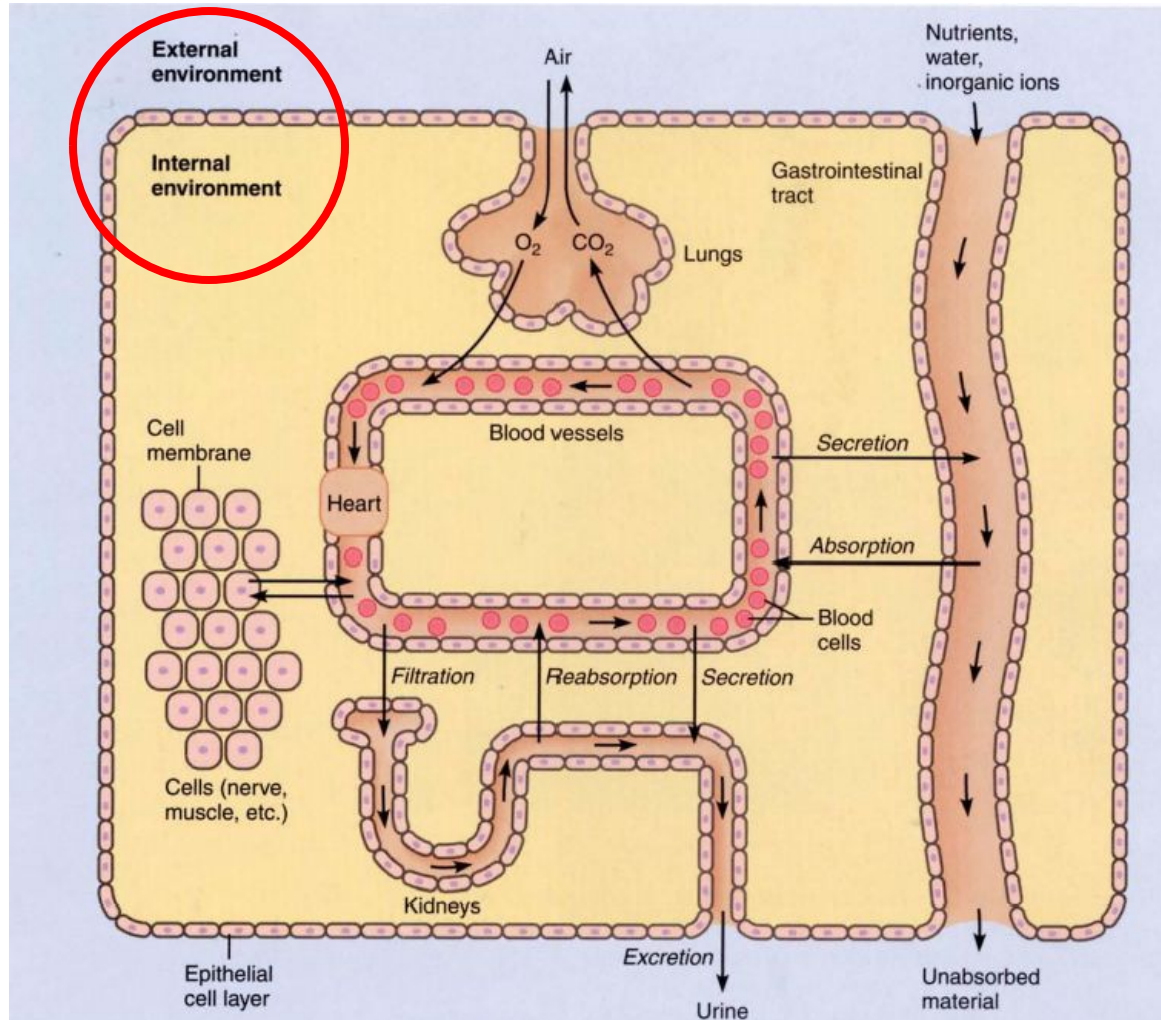
2. Internal environment (liquid)

- Relatively stable*
- Actively maintained by cells & organs which live in it*

First to recognize that the internal environment is under sophisticated physiological regulation

Body Compartments

Overall Plan of Human Body



Respiratory, gastrointestinal, & renal systems

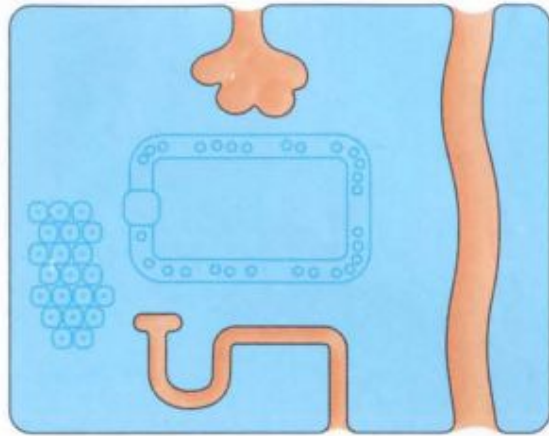
Communicate with external environment

Cardiovascular system

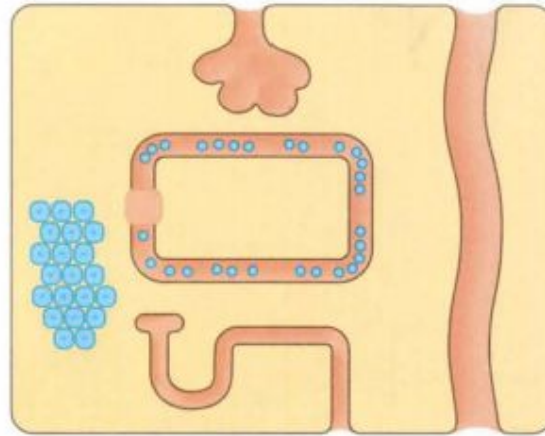
Transports nutrients & wastes

Flows of materials are indicated by arrows

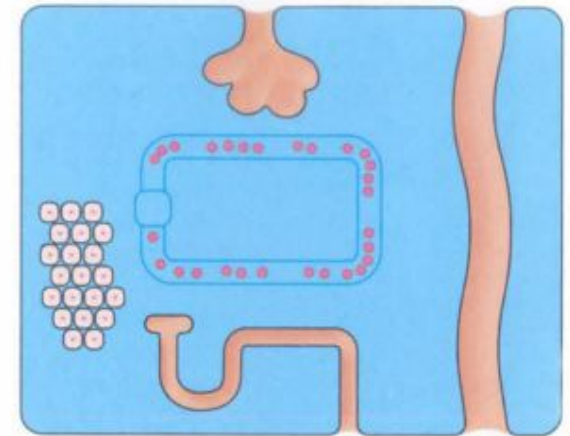
Body Fluid Compartments



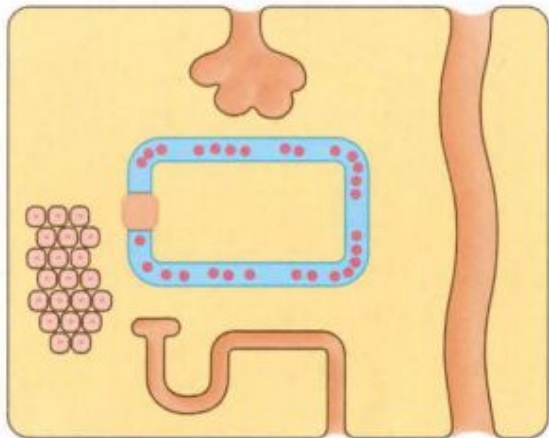
(a) Total body water (TBW)



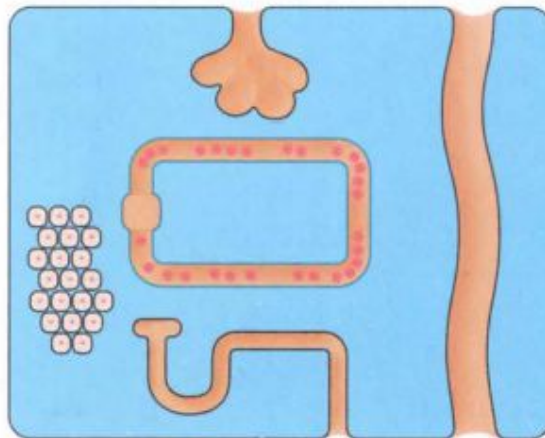
(b) Intracellular fluid (ICF)



(c) Extracellular fluid (ECF)



(d) Plasma



(e) Interstitial fluid (ISF)

Body fluid	Volume (L)
TBW	42
ICF	28
ECF	14
Plasma	3
ISF	11

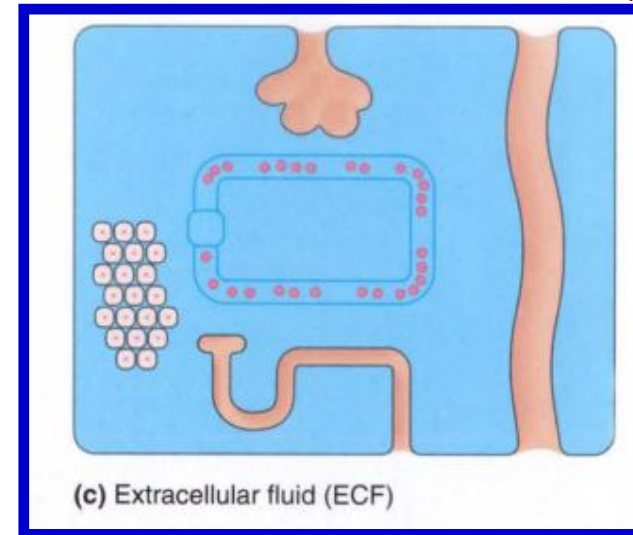
(f) Distribution of TBW

Body fluid is indicated in blue

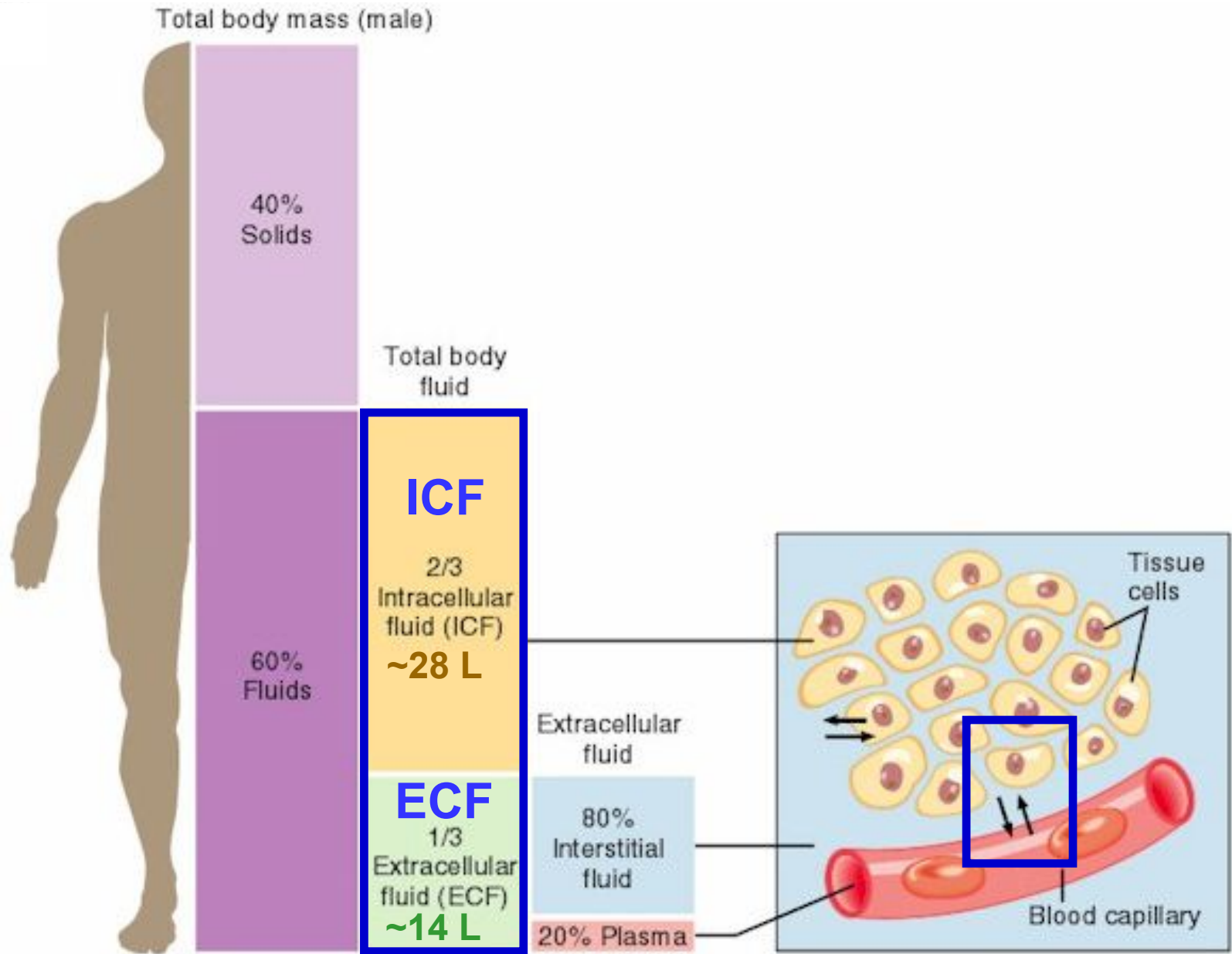
Body Fluid Compartments

ECF

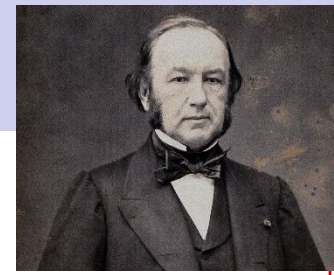
- Fluid surrounding cells
- Vehicles through which materials pass to & from cells
- Constantly changing to attain & maintain optimal conditions & concentrations



Body Fluid Compartments



Homeostasis



Claude Bernard (1813-1878) – French physiologist

“The constancy of the internal environment is the condition for the free and independent life.”



Concept of homeostasis

Homeostasis

Walter Bradford Cannon (1871-1945) – *American physiologist*

Expanded on Claude Bernard's concept of homeostasis



1. Homeostasis

Uniform conditions that prevail in the body in face of all the disturbances that tend to change them

Establishment of optimum condition for physiological functions

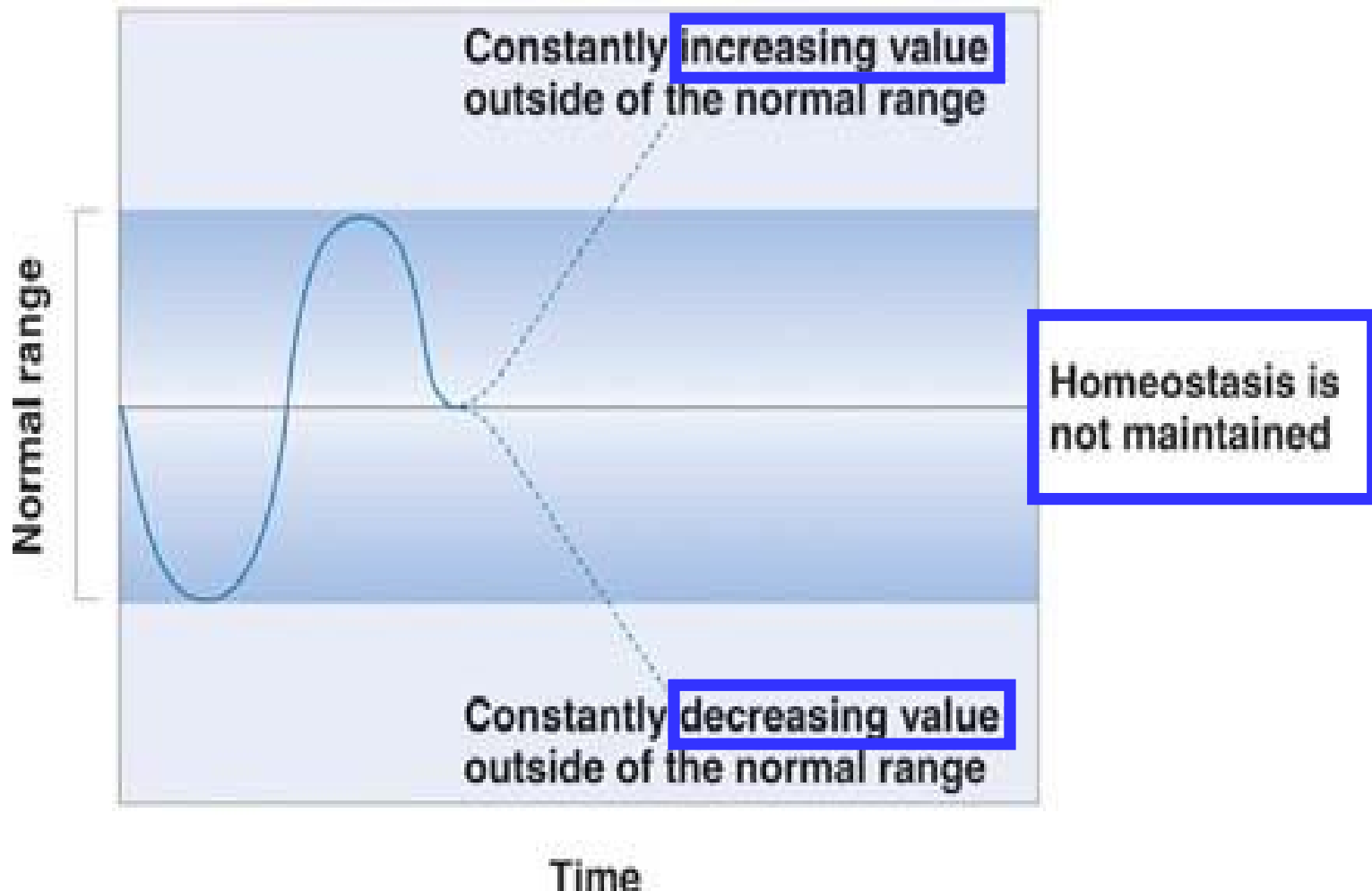
2. A homeostatic mechanism -

for preservation of dynamic constancy of internal environment in which the cells of the body bathe

Recognize that the key to maintaining a stable internal environment is the presence of regulatory mechanism

Homeostatic Regulation

- The **maintenance** of a stable internal environment requires **constant monitoring** & **adjustments** as condition changes



Homeostasis

Normal range of important constituents & physical characteristics of ECF

	Normal range	units
Oxygen	35-40	mmHg
Carbon dioxide	35-45	mmHg
Sodium ions	138-146	mmol/L
Potassium ions	3.8-5.0	mmol/L
Calcium ions	1.0-1.4	mmol/L
Chloride ions	103-112	mmol/L
Bicarbonate ions	24-32	mmol/L
Glucose	75-95	Mg/dl
Body temperature	98-98.8 (37.0)	°F (°C)
Acid-base	7.3-7.5	pH

- Homeostatic control cannot maintain complete constancy
- Regulated variables have a **range of normal values** (depending on the conditions)

Homeostasis

Normal range of important constituents
& physical characteristics of ECF

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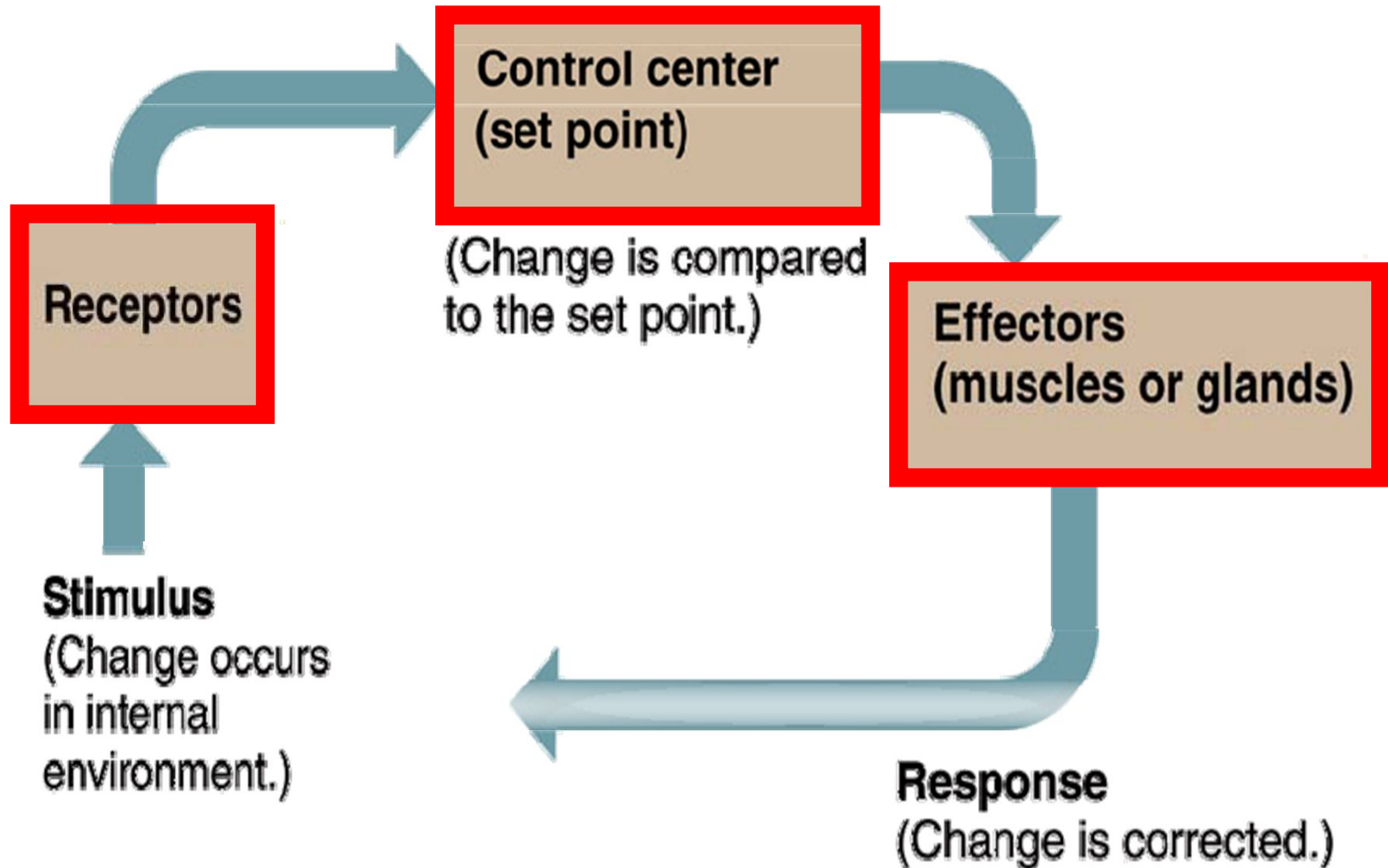
How is homeostasis maintained?

- Homeostatic control cannot maintain
- Regulated variables have a **range of normal values** (depending on the conditions)

Homeostatic Control Systems

3 components

- Nervous system
- Endocrine system



Control Mechanisms in the Body

1. Negative Feedback Control

- *Adopted by most control systems*
- *Involved in homeostatic control*

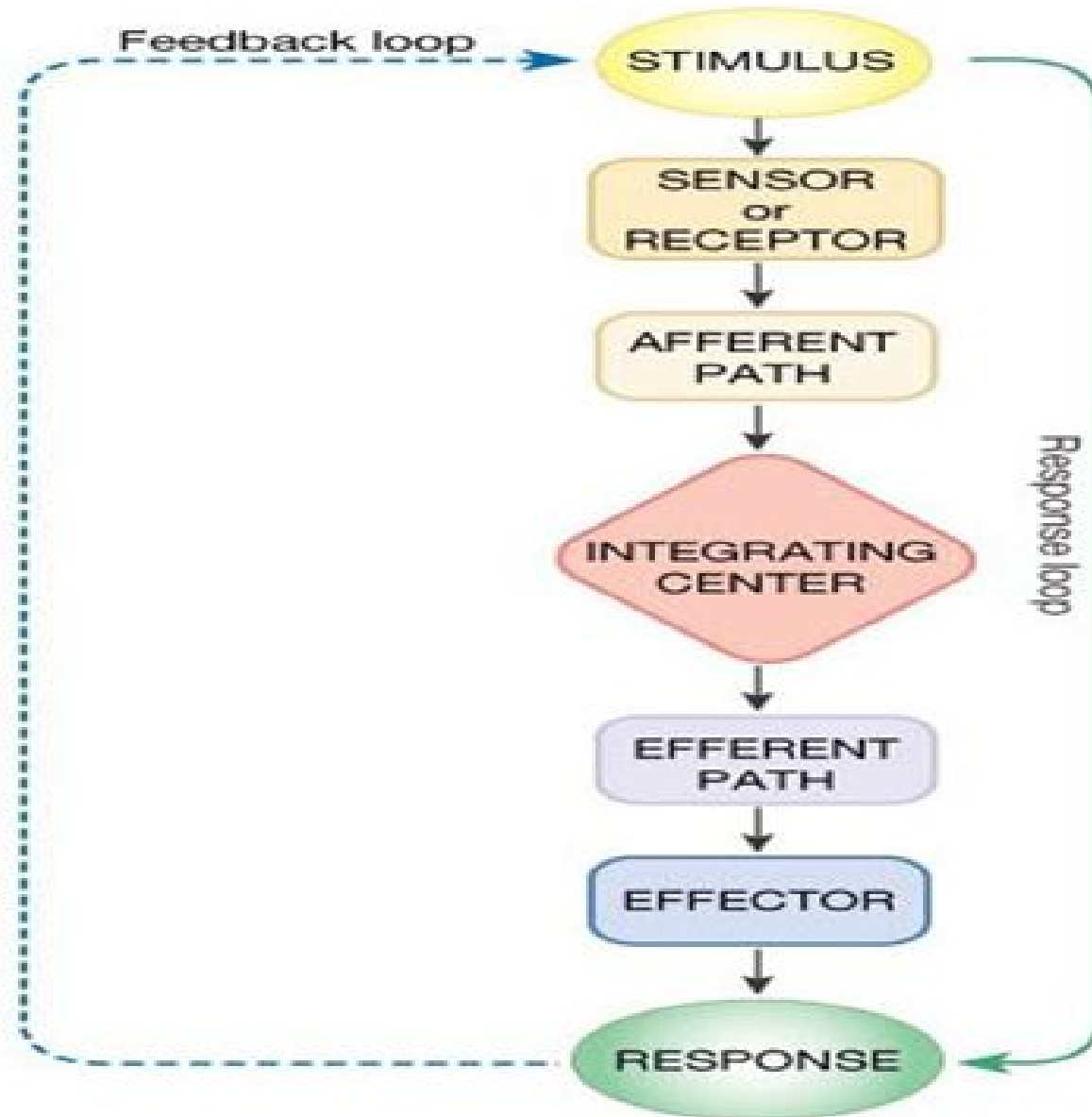
2. Positive Feedback Control

- *For a transient physiological change*
- *NOT for homeostatic control*

3. Feedforward Control

- *Proactive – prompt the system to act before the changes begin to affect it*

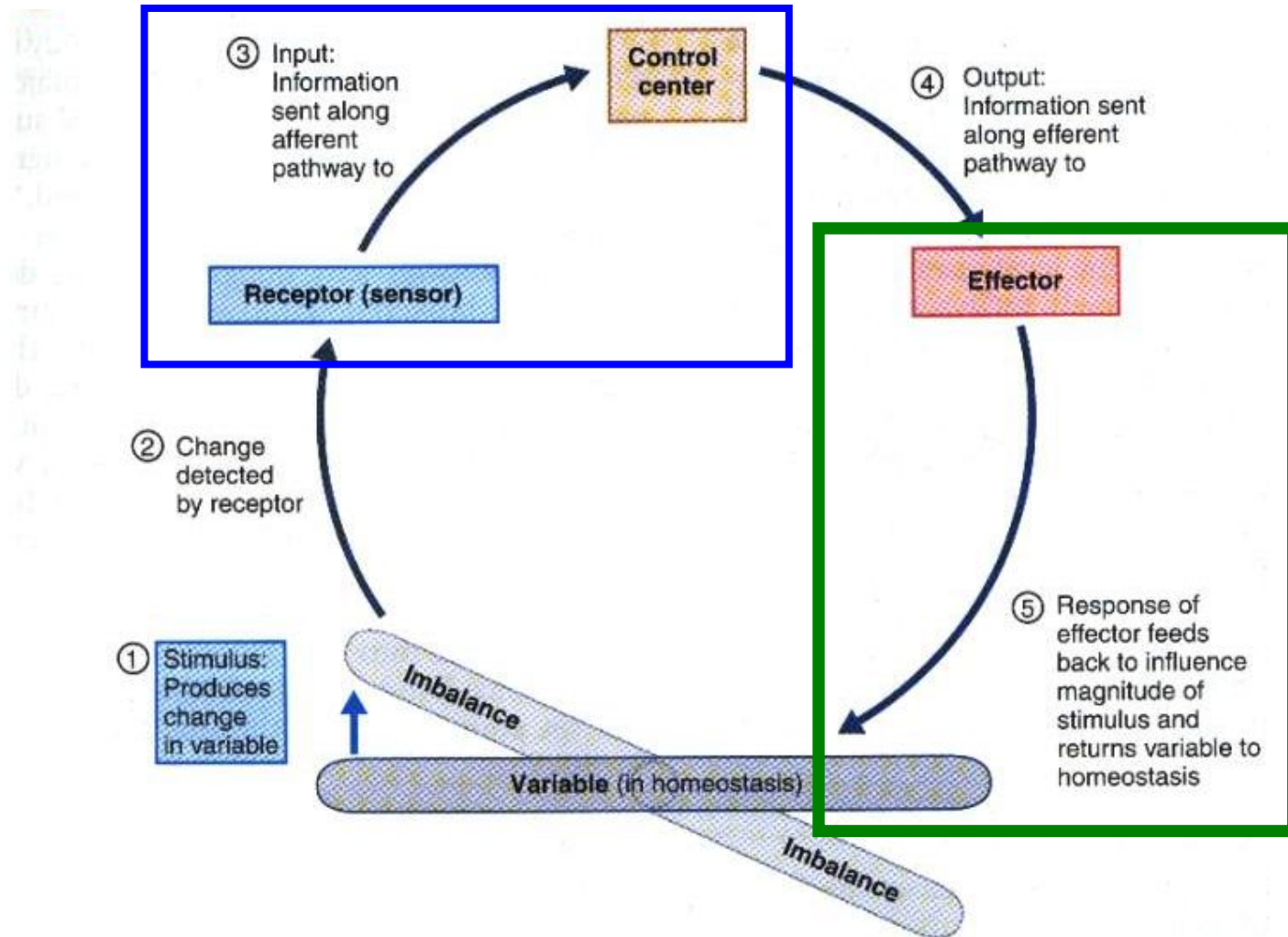
Negative Feedback



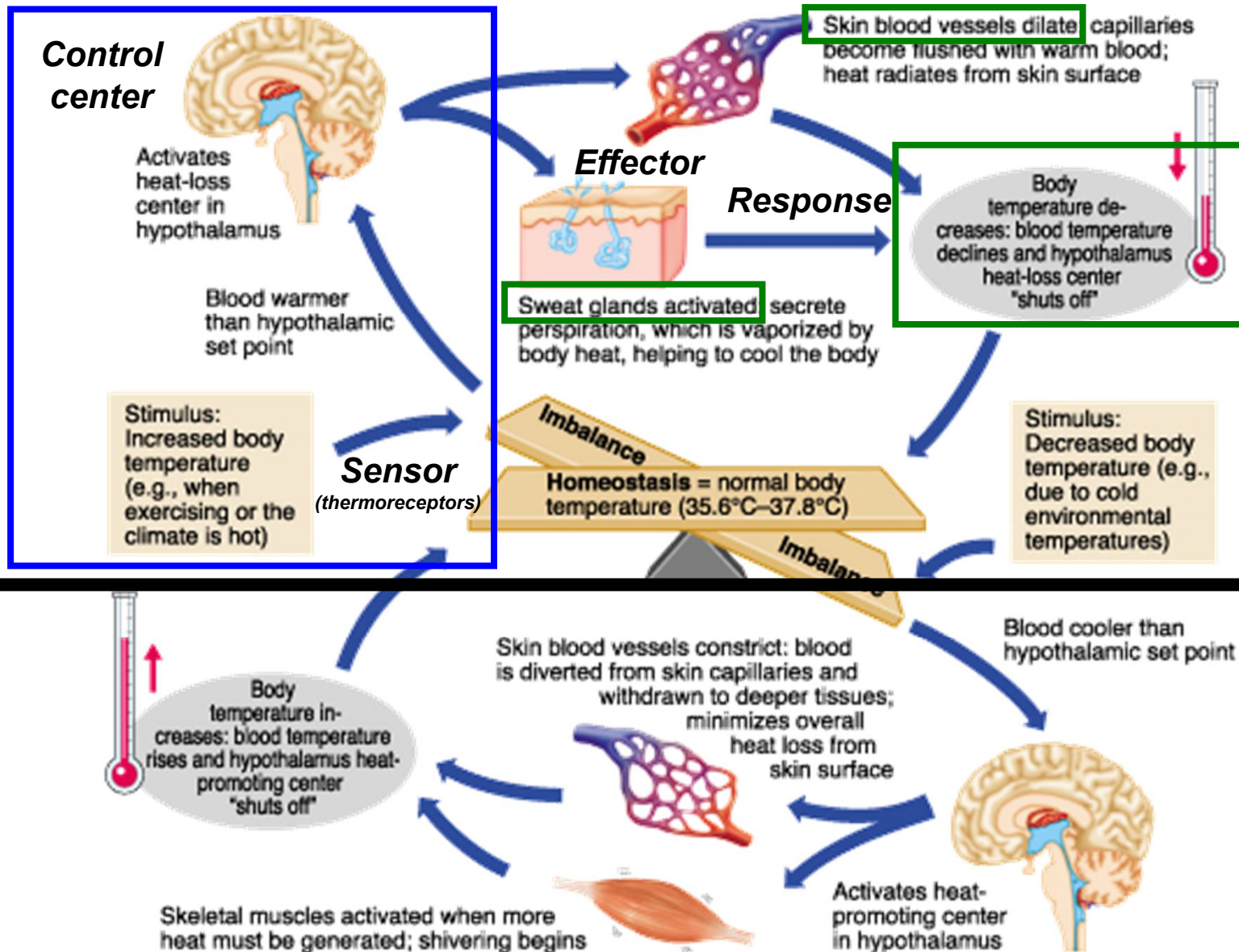
Negative Feedback

Output shuts off the original stimulus

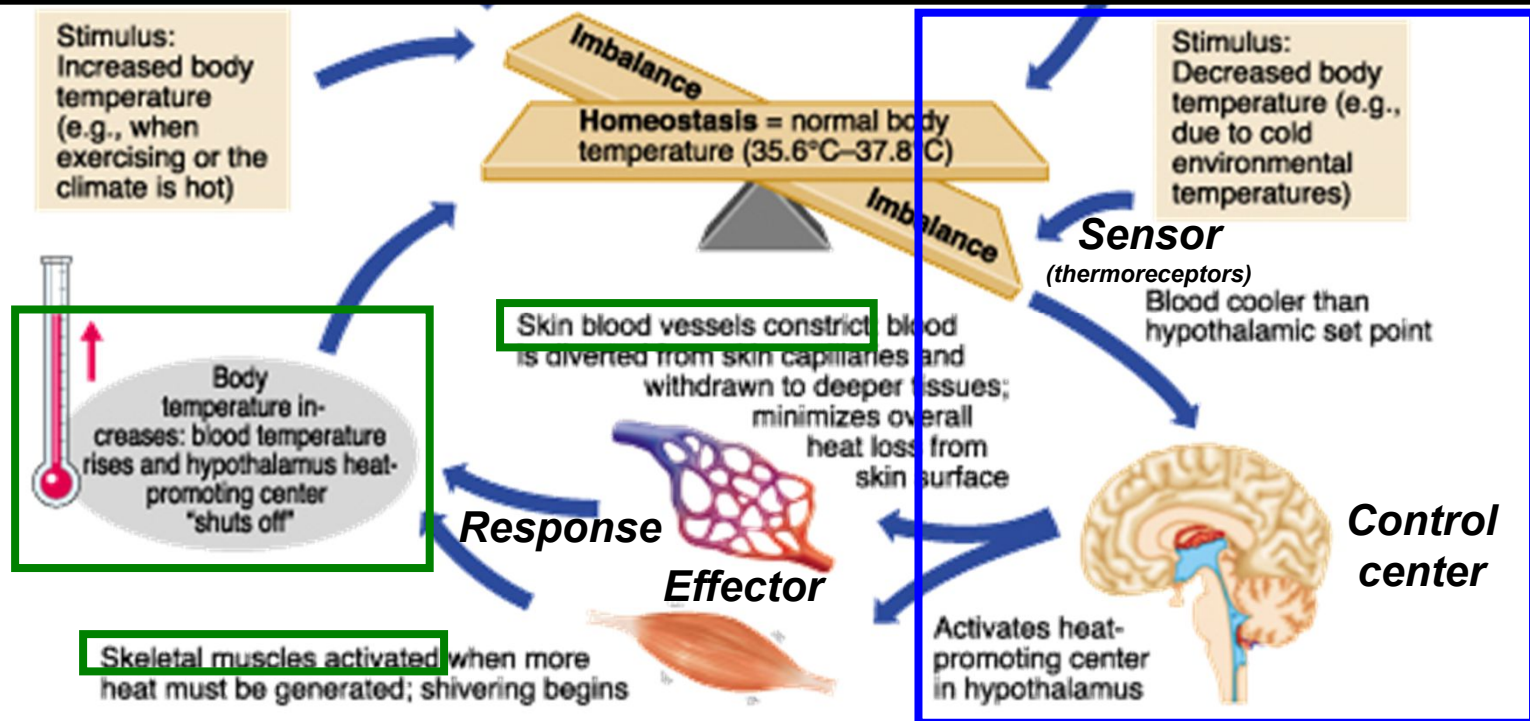
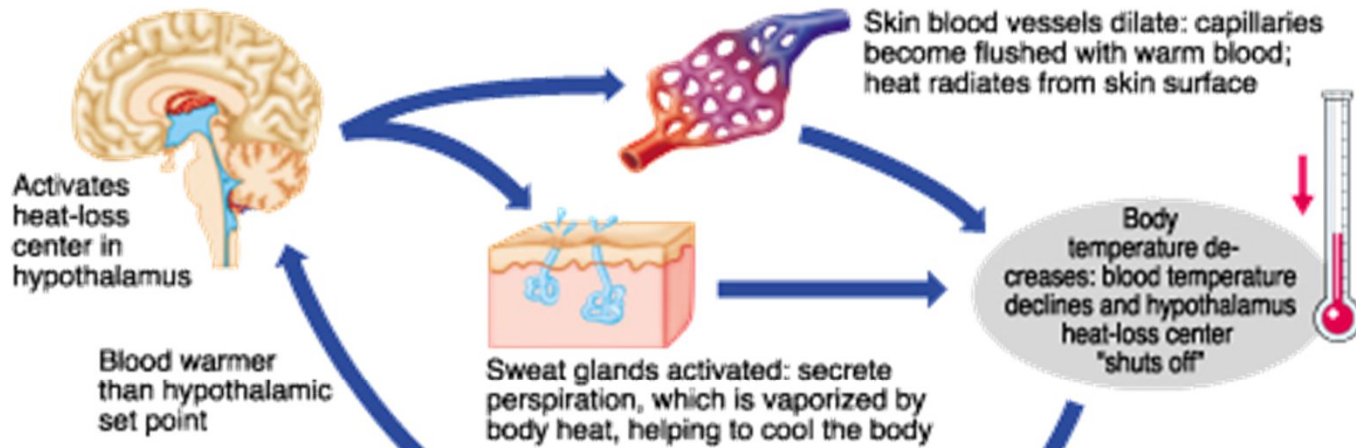
→ Physiological event returns to optimal status



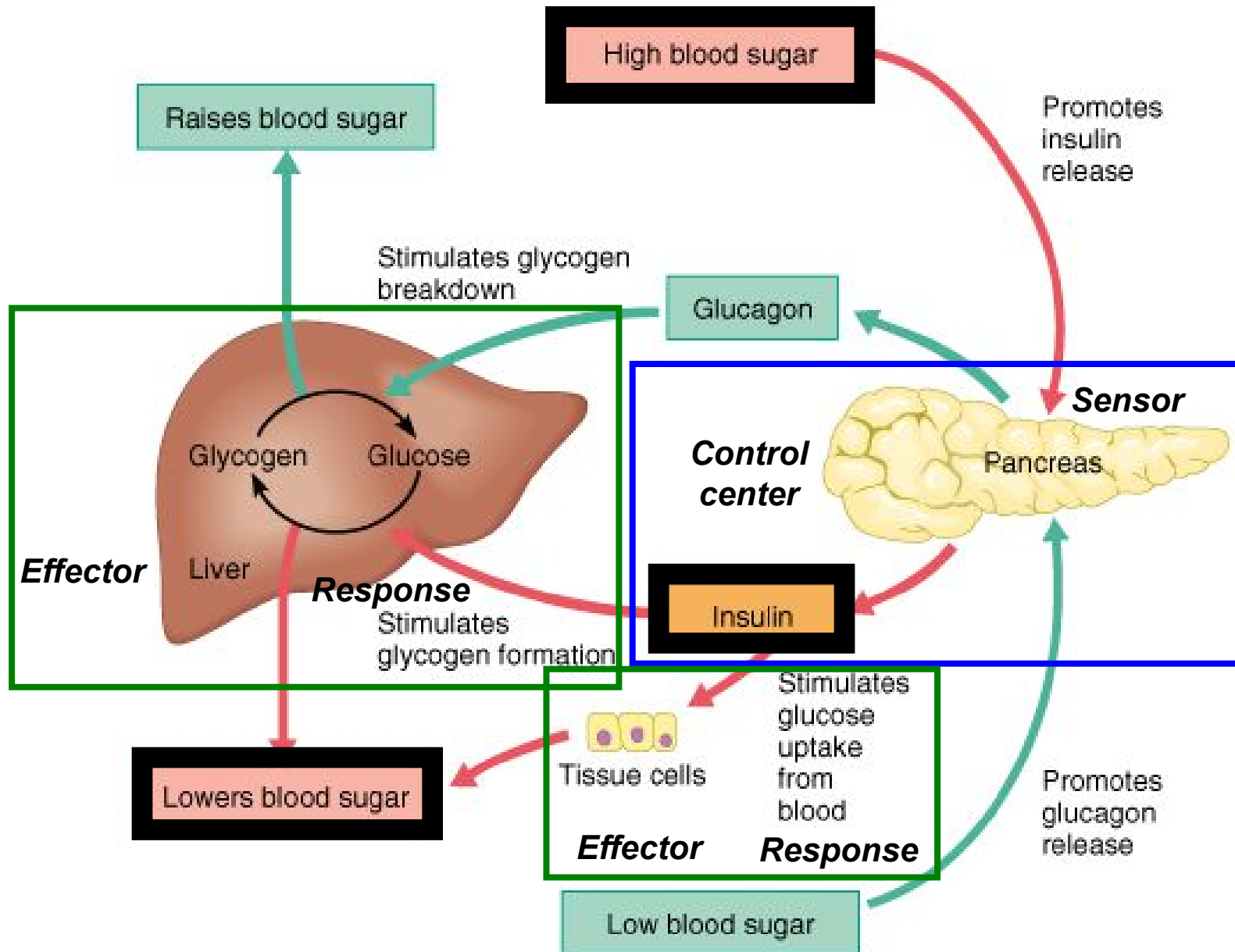
Example 1: Body temperature



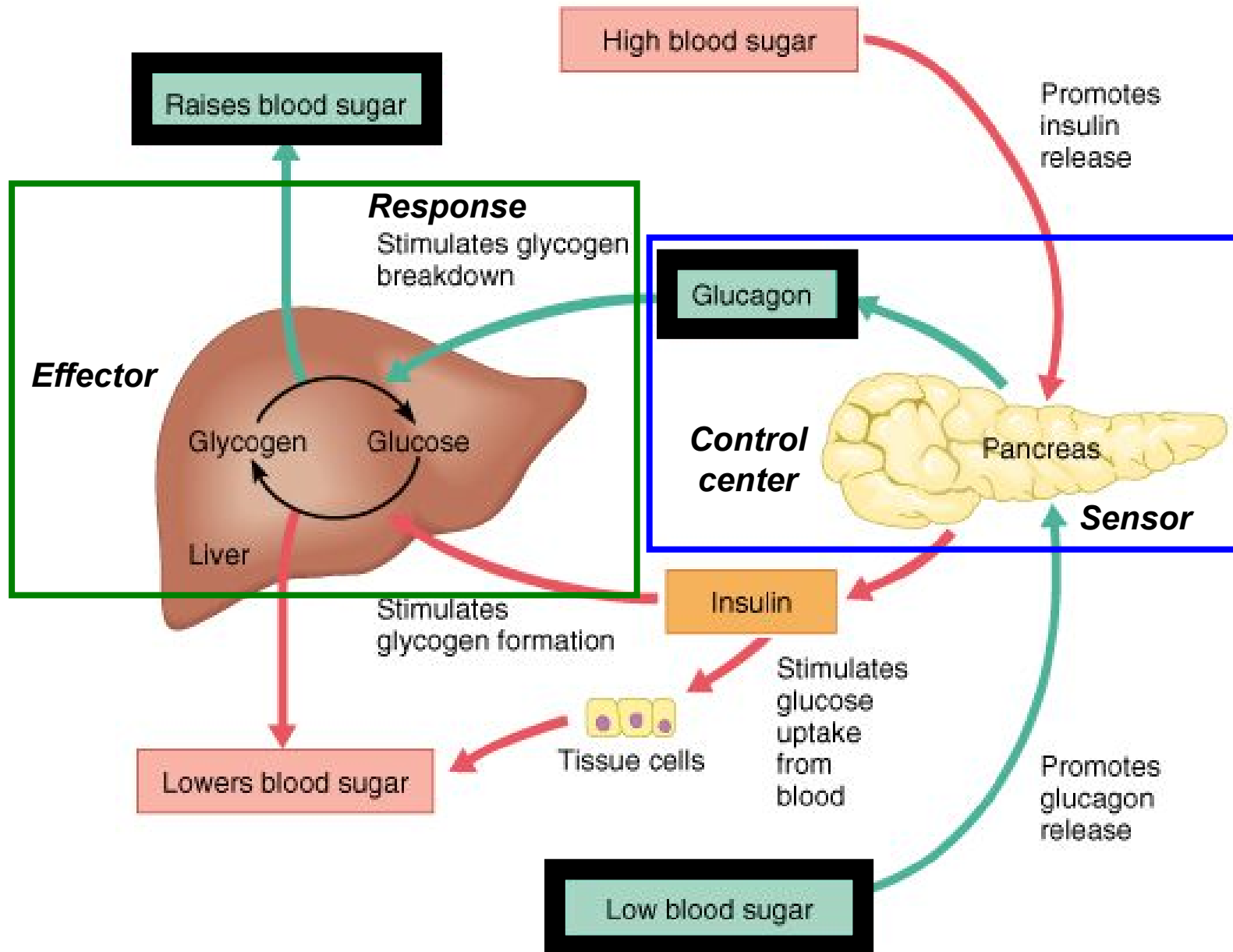
Example 1: Body temperature



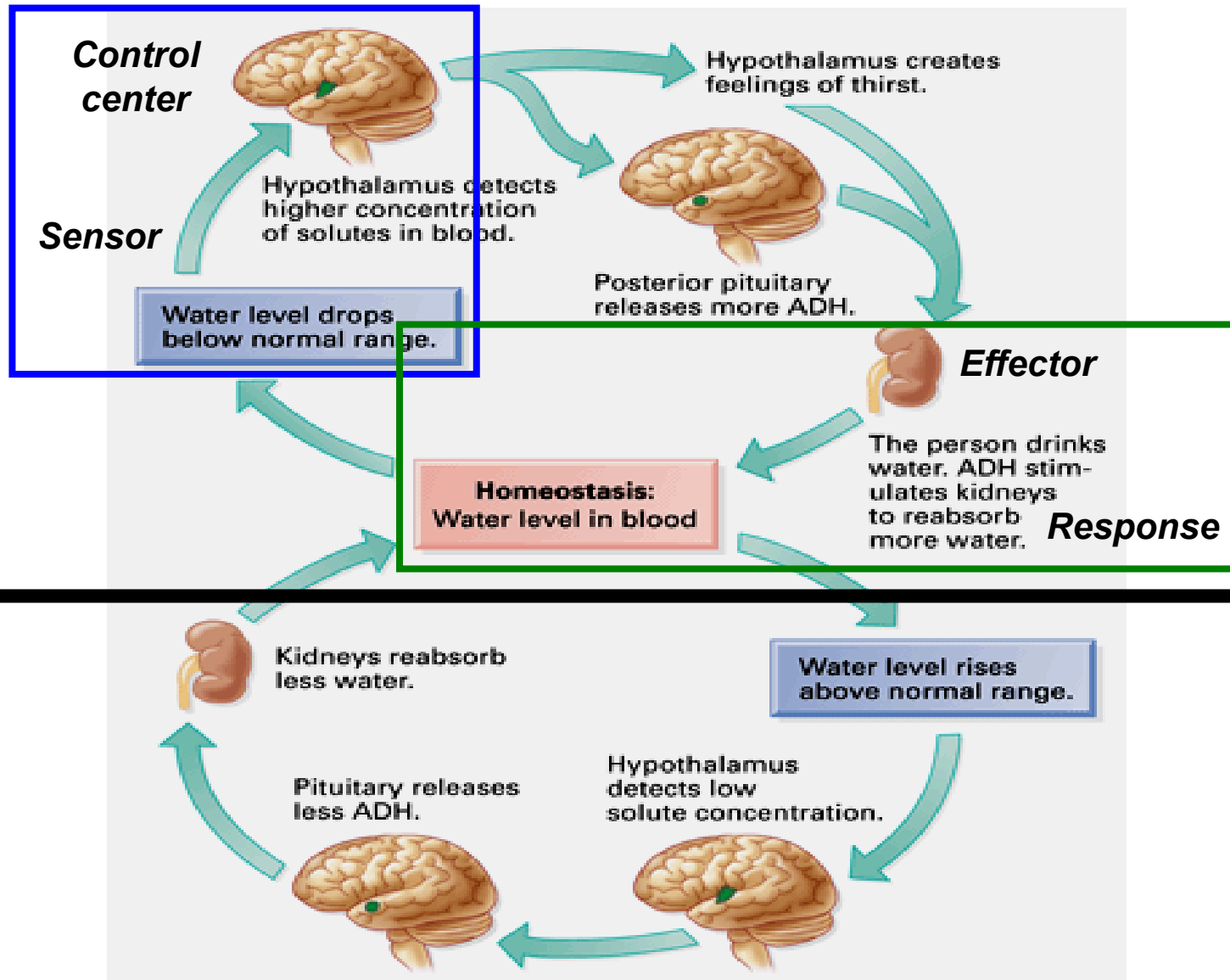
Example 2: Blood glucose level



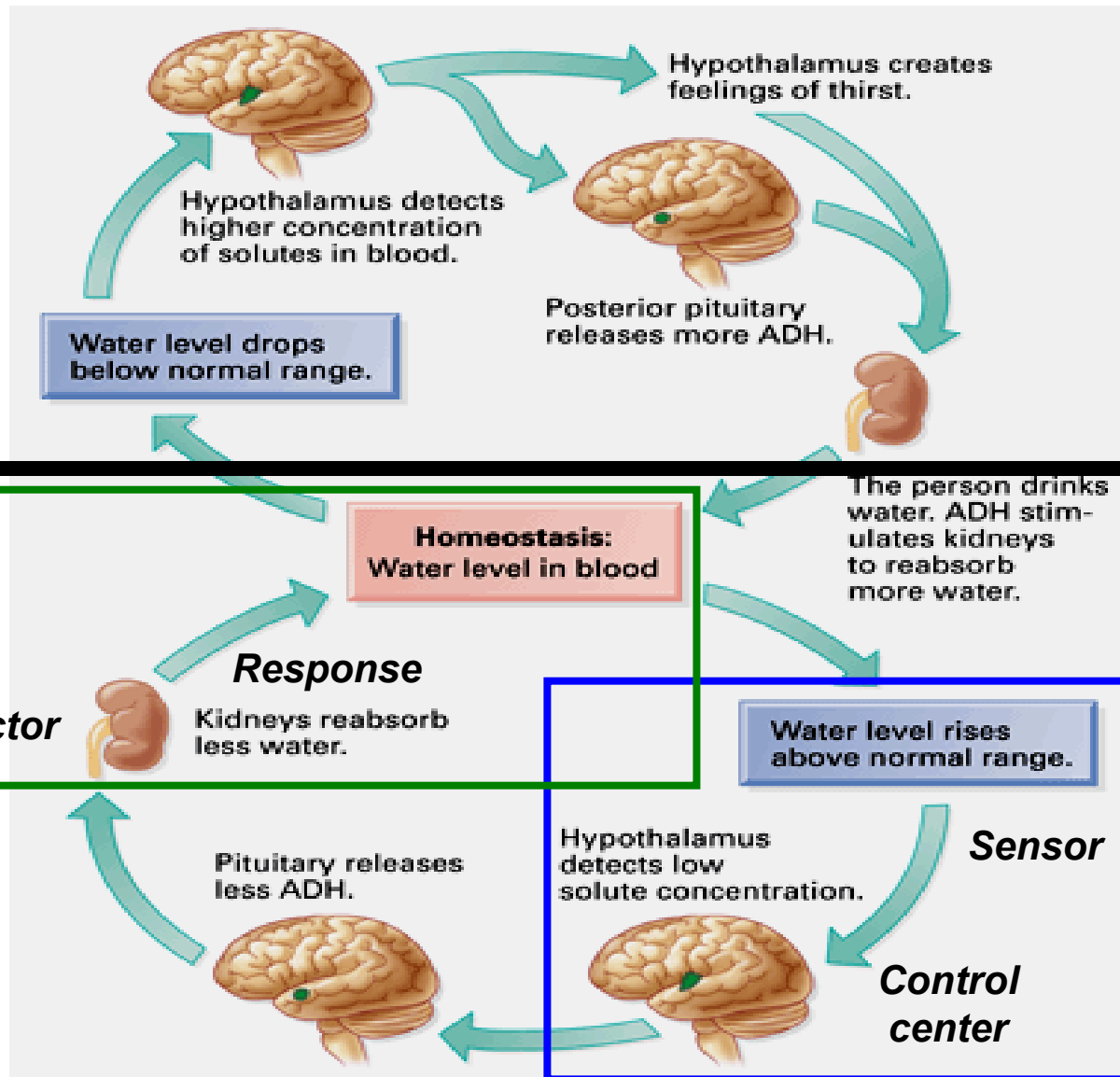
Example 2: Blood glucose level



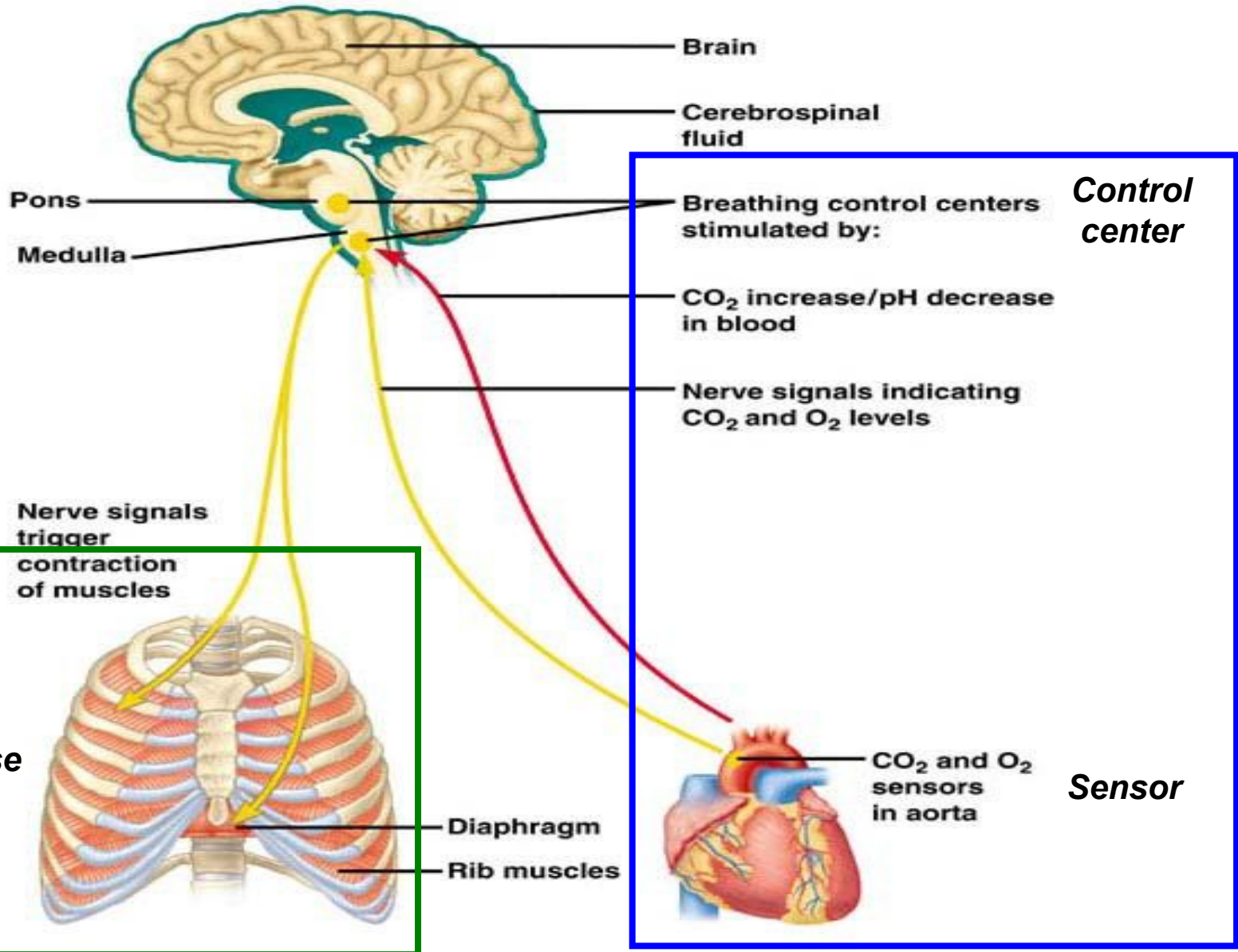
Example 3: Water level in blood



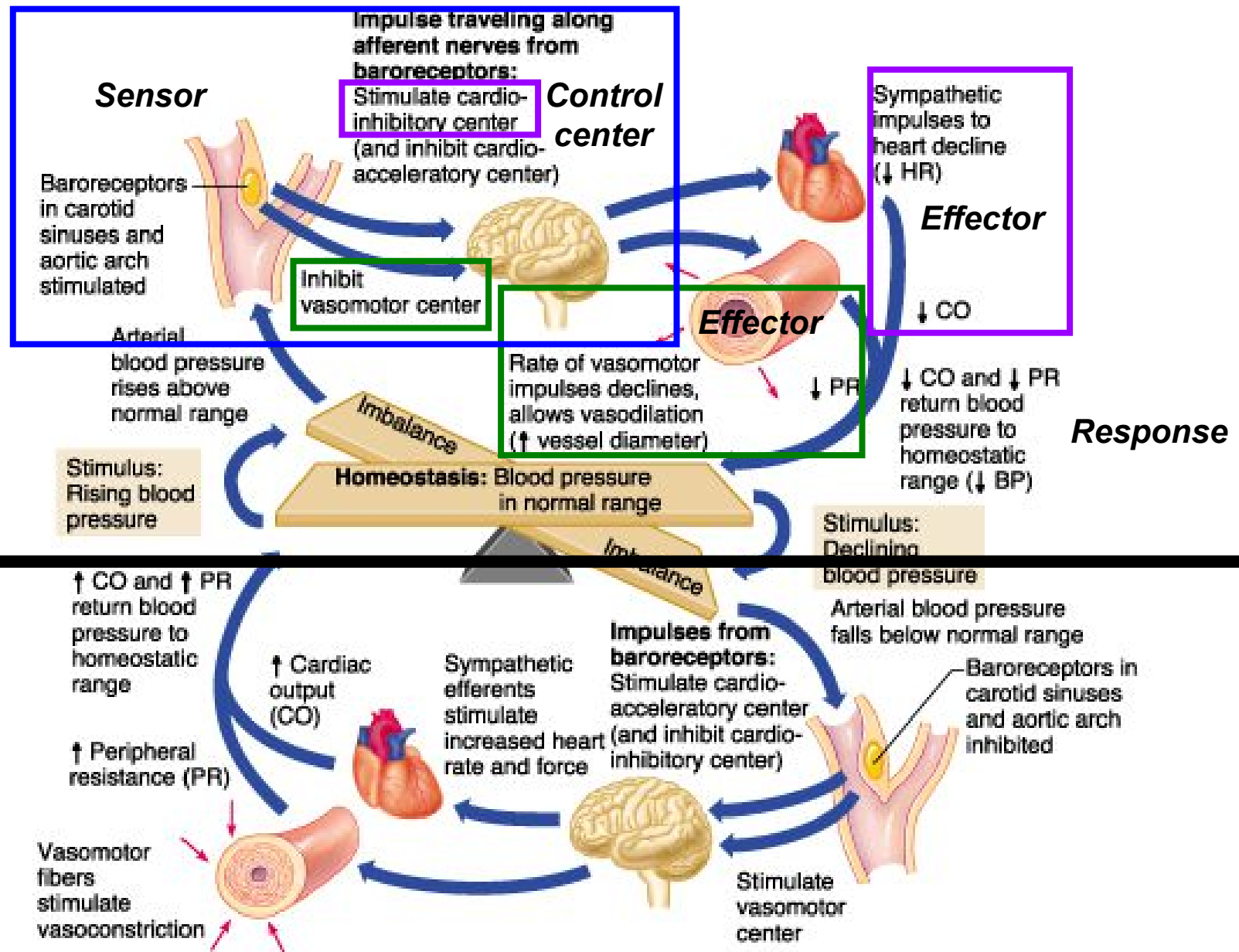
Example 3: Water level in blood



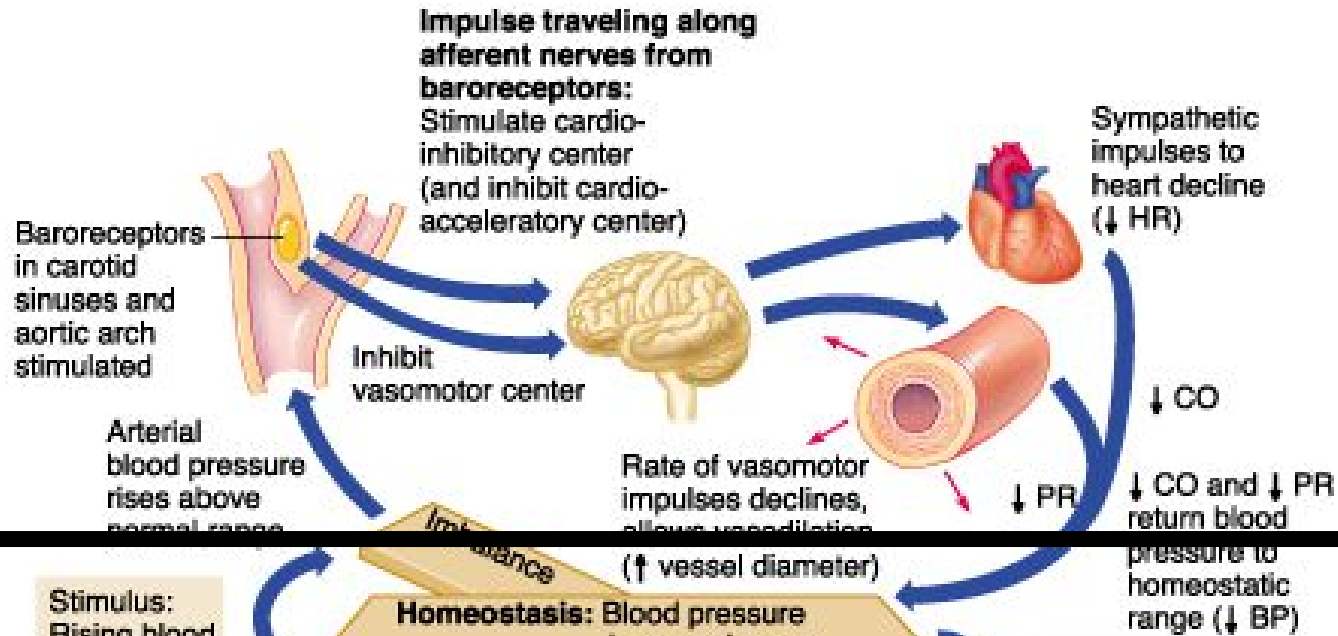
Example 4: Blood gas level



Example 5: Blood pressure



Example 5: Blood pressure



Response

Stimulus:
Rising blood pressure

\uparrow CO and \uparrow PR
return blood pressure to homeostatic range

\uparrow Peripheral resistance (PR)

Vasomotor fibers stimulate vasoconstriction

Effector

\uparrow Cardiac output (CO)

Sympathetic efferents stimulate increased heart rate and force

Effector

Impulses from baroreceptors:

Stimulate cardio-acceleratory center (and inhibit cardio-inhibitory center)

Control center

Stimulate vasomotor center

Stimulus:
Declining blood pressure

Arterial blood pressure falls below normal range

Sympathetic impulses to heart decline (\downarrow HR)

\downarrow CO

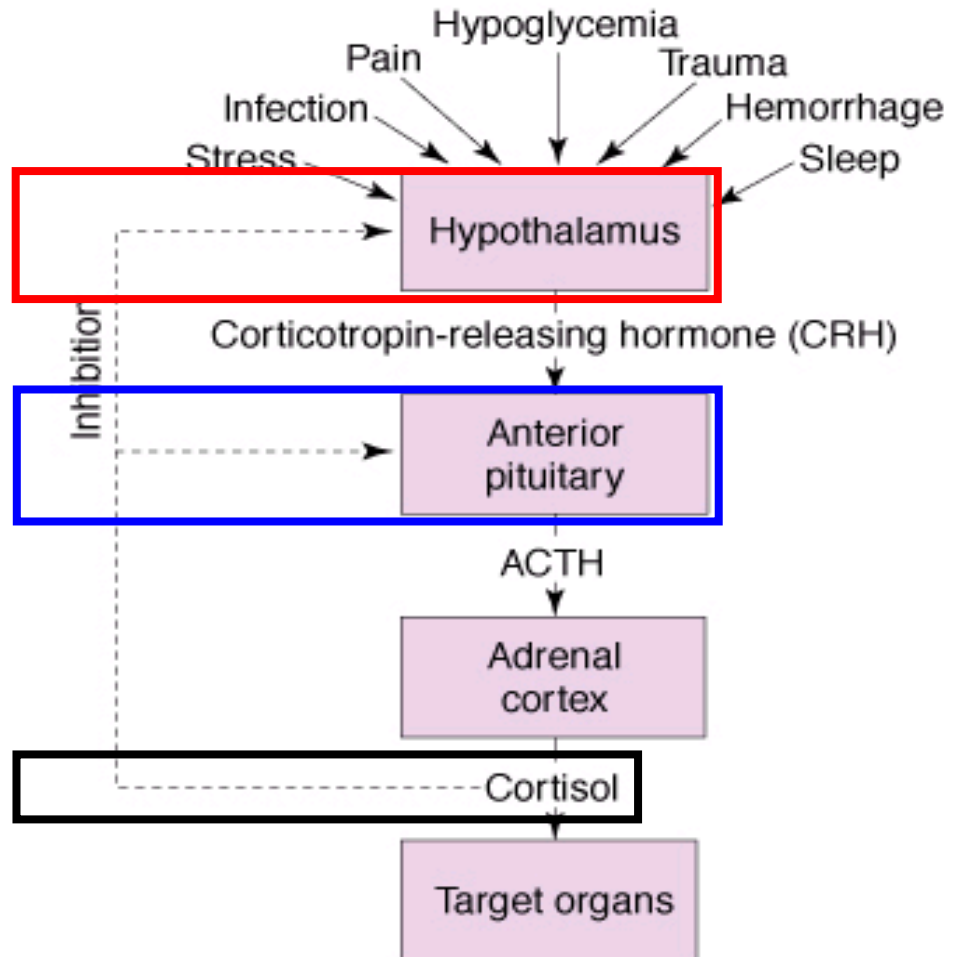
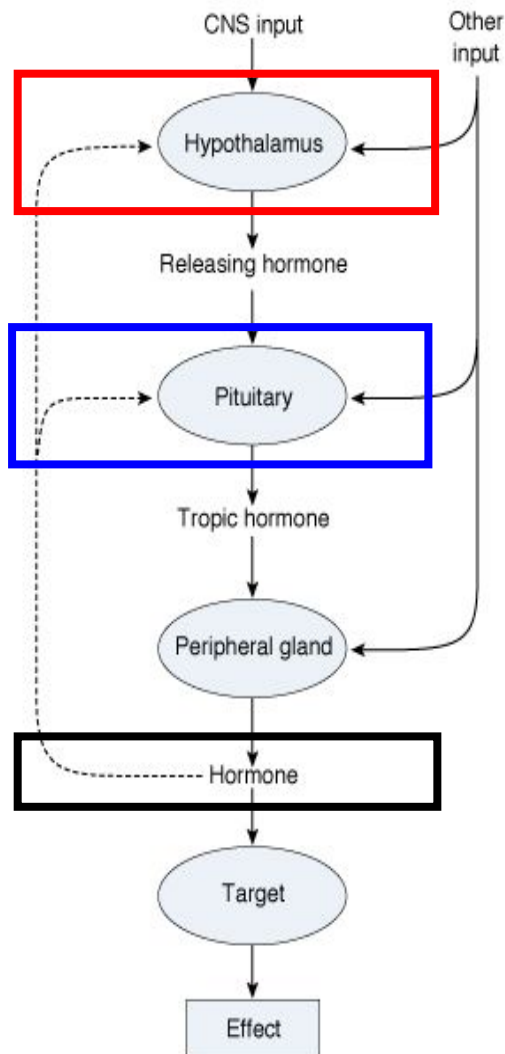
\downarrow CO and \downarrow PR return blood pressure to homeostatic range (\downarrow BP)

Sensor

Baroreceptors in carotid sinuses and aortic arch inhibited

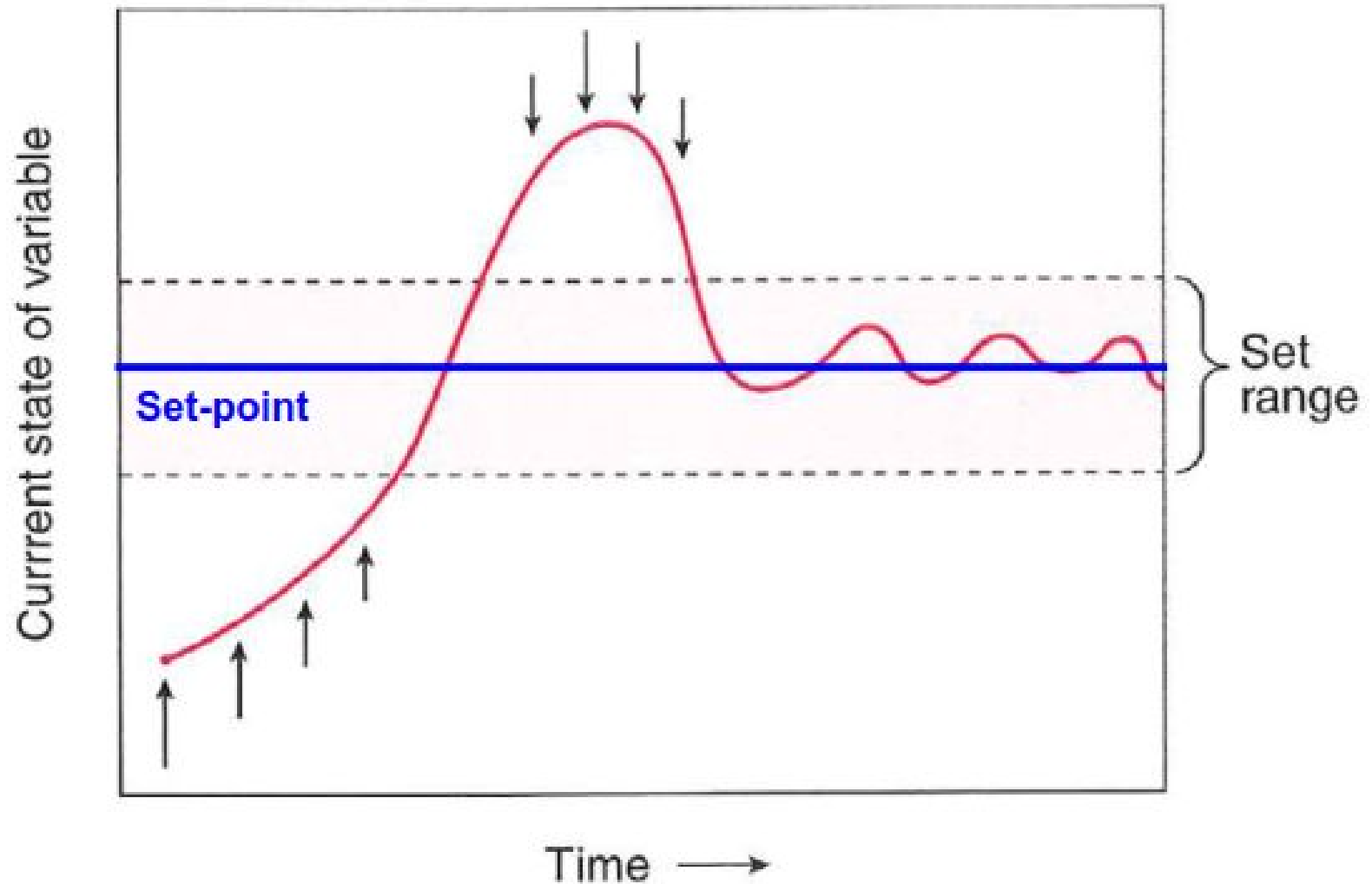
Example 6: Endocrine gland secretions (hormones)

Hypothalamic–pituitary–adrenal axis



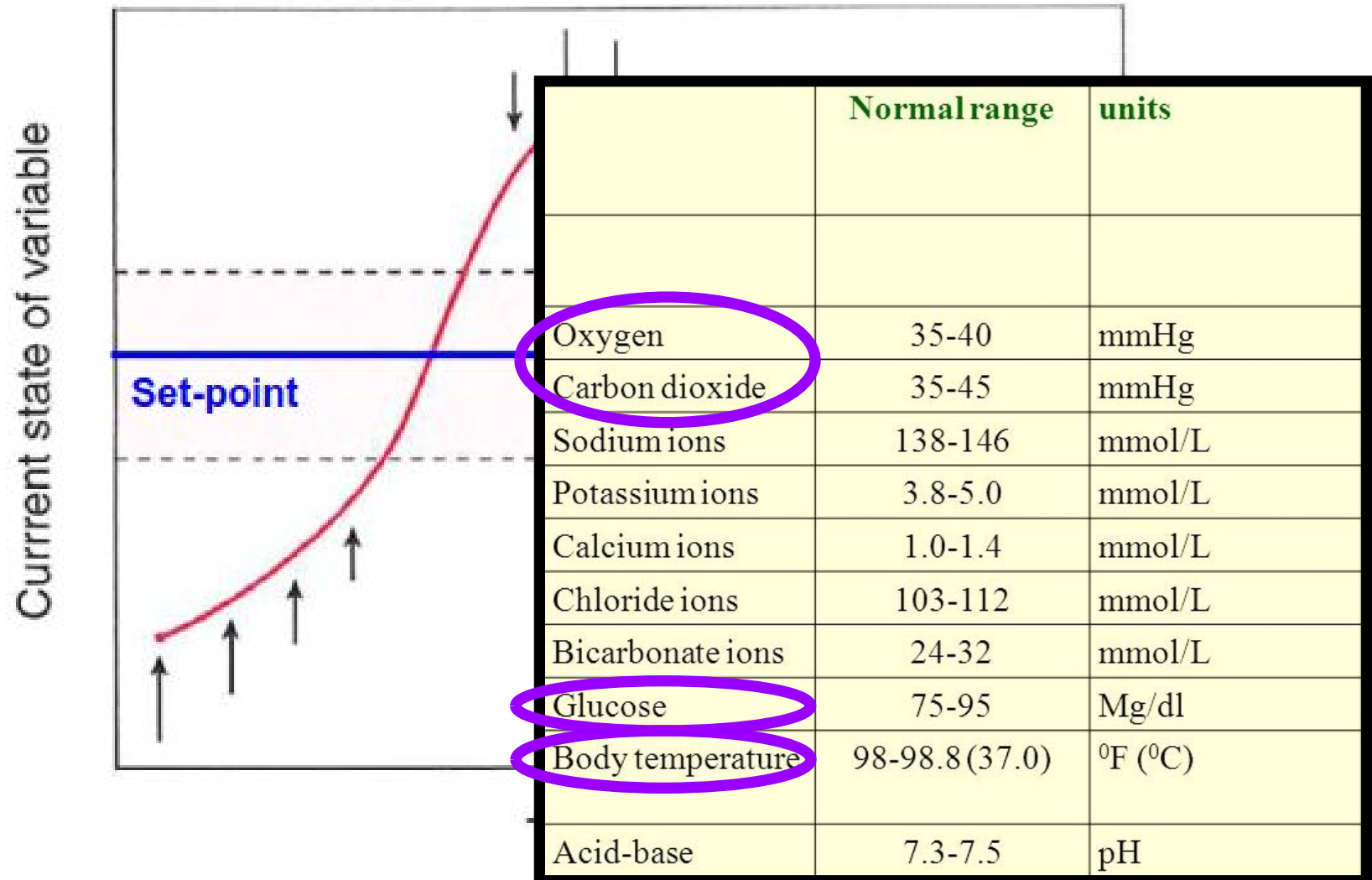
Negative Feedback

The variable is restored toward a pre-determined set-point



Negative Feedback

The variable is restored toward a pre-determined set-point



Control Mechanisms in the Body

1. Negative Feedback Control

- *Adopted by most control systems*
- *Involved in homeostatic control*

2. Positive Feedback Control

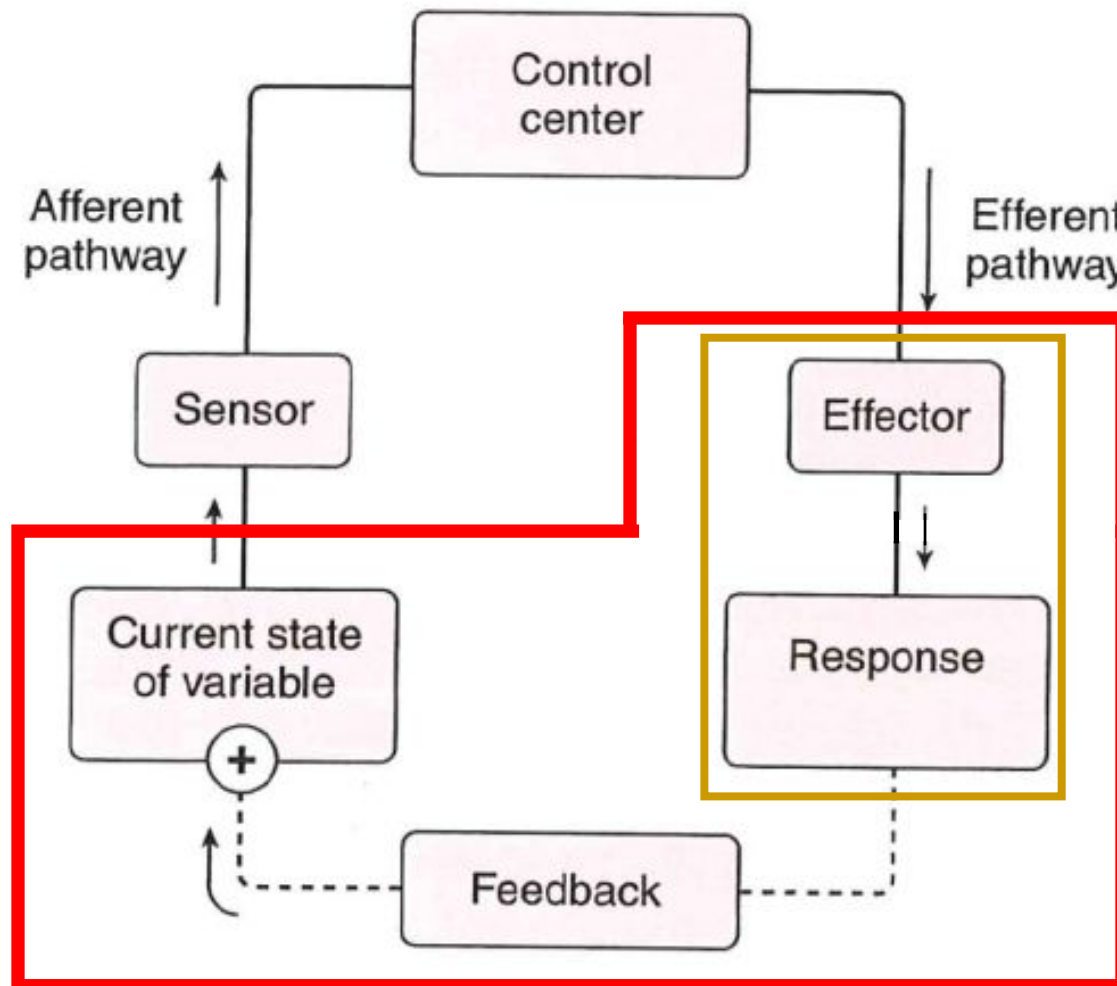
- *For a transient physiological change*
- ***NOT for homeostatic control***

3. Feedforward Control

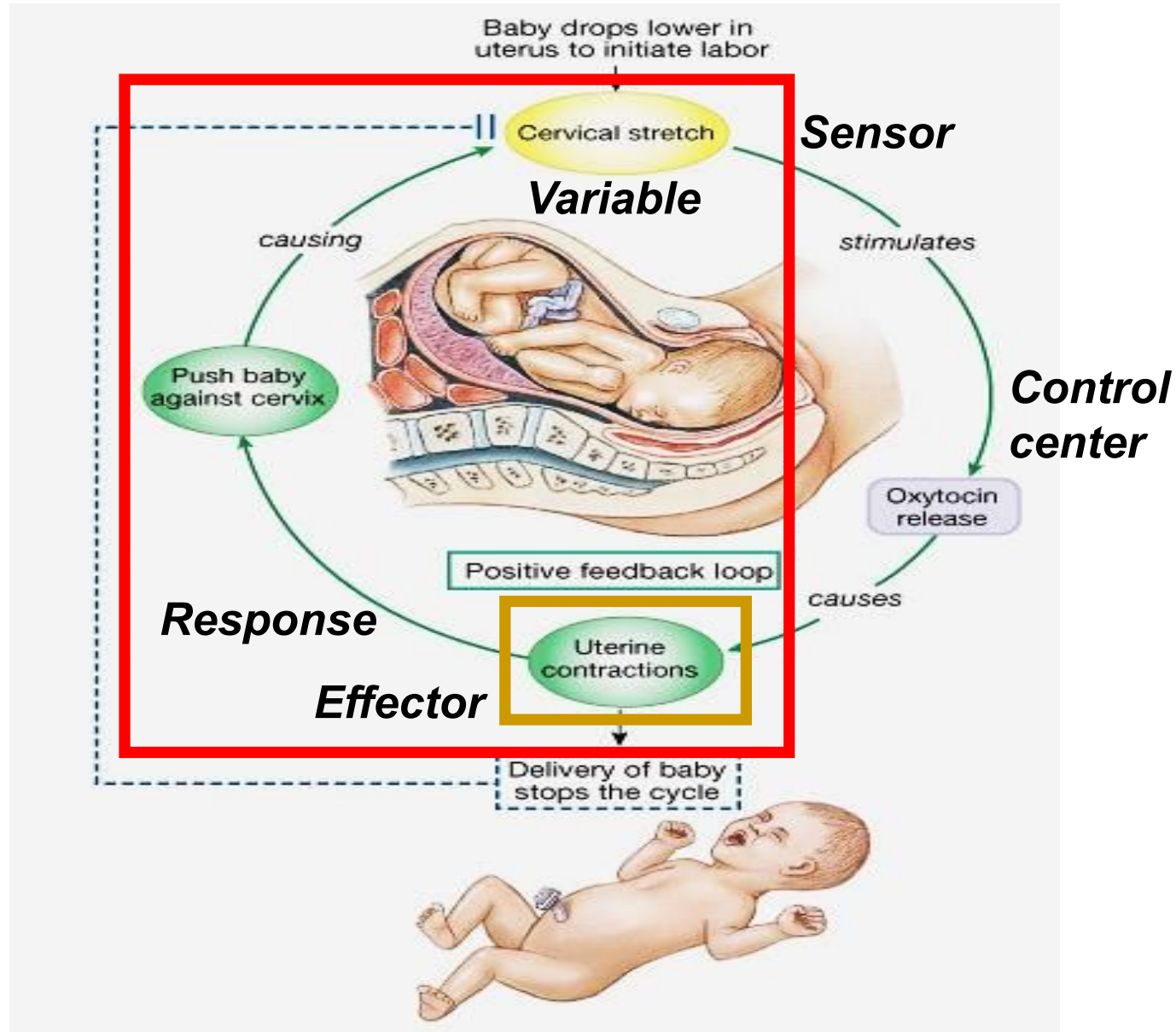
- *Proactive – prompt the system to act before the changes begin to affect it*

Positive Feedback

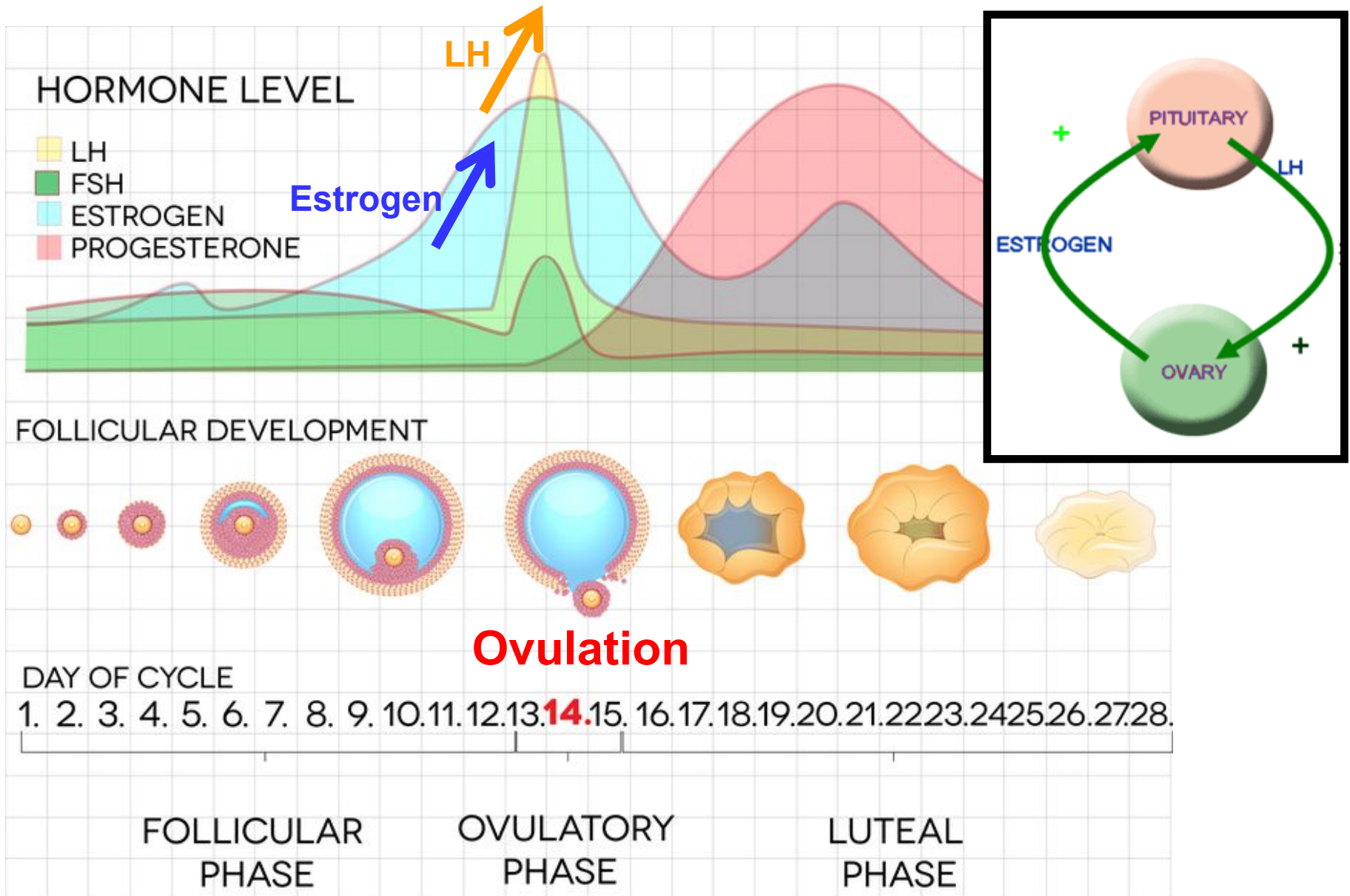
- The **response** enhances the change that set it in motion.
- The **output** exaggerates the original stimulus.



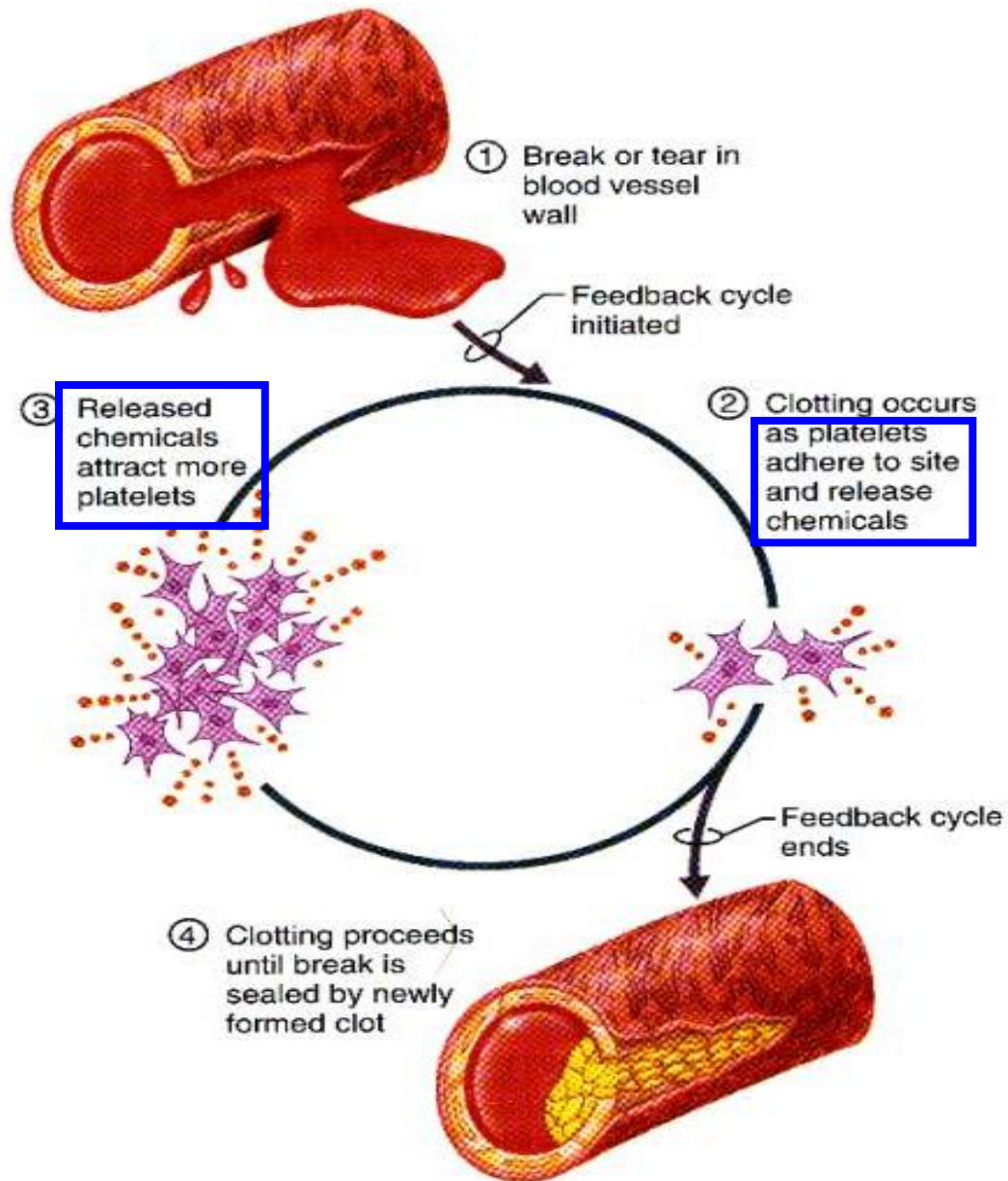
Example: Parturition



Example 2: Ovulation

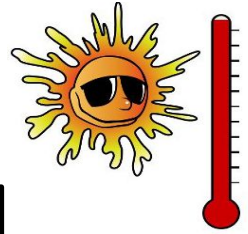


Example 3: Blood clotting



Example 4: Heat stroke

Breakdown of thermoregulatory centre



Body temperature is elevated



Hypothalamus is depressed

Metabolic rate is increased



Ineffective heat loss [no sweating]

Increased heat generation by metabolism

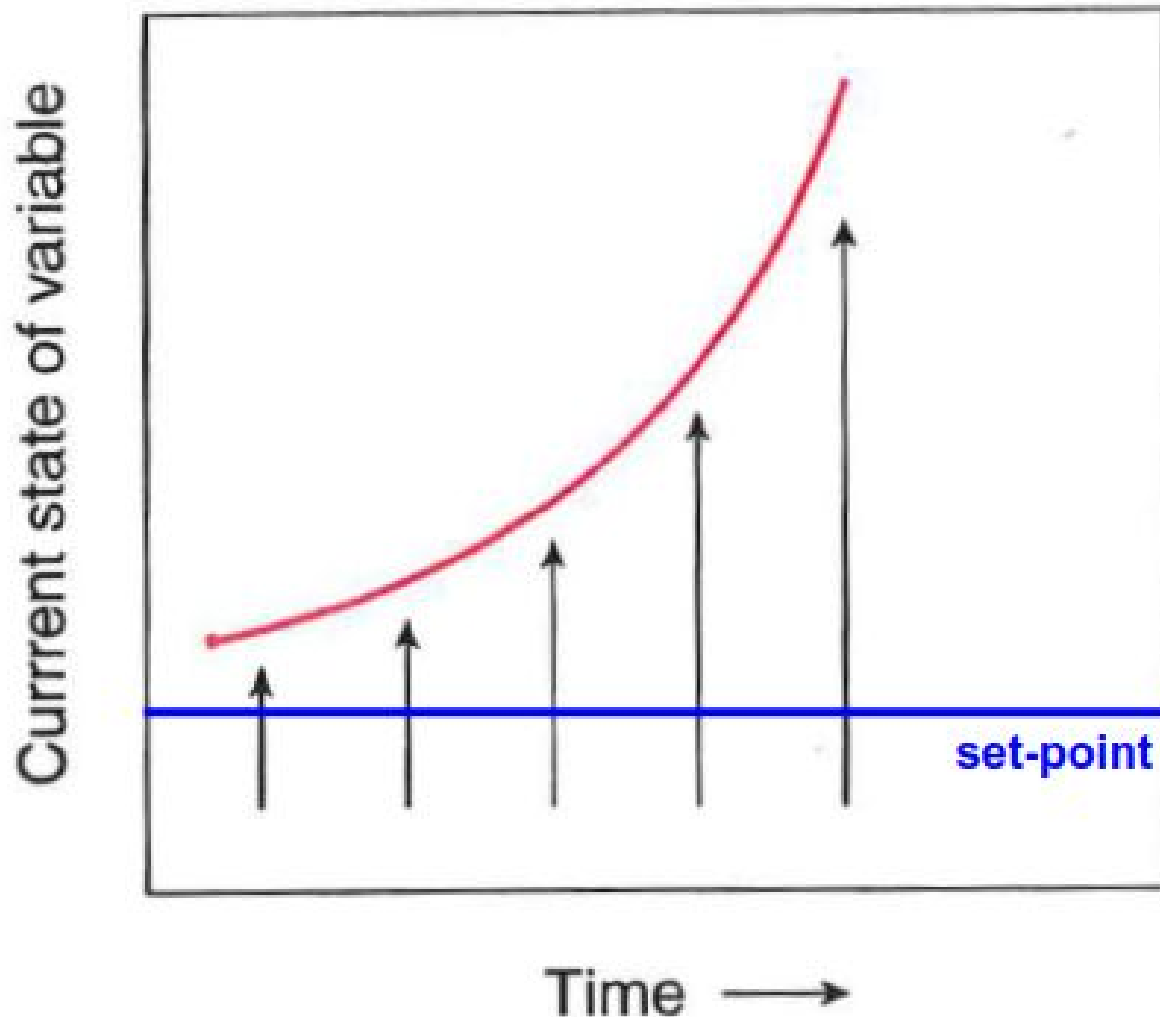
Positive feedback



Body temperature increases sharply

Positive Feedback

The variable is moved farther away from the initial set-point



Control Mechanisms in the Body

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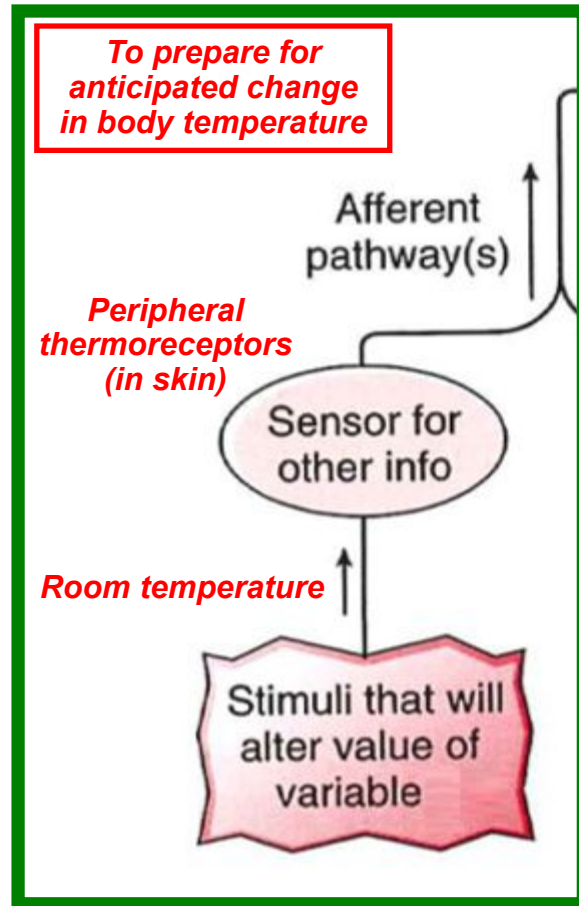
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3. Feedforward Control

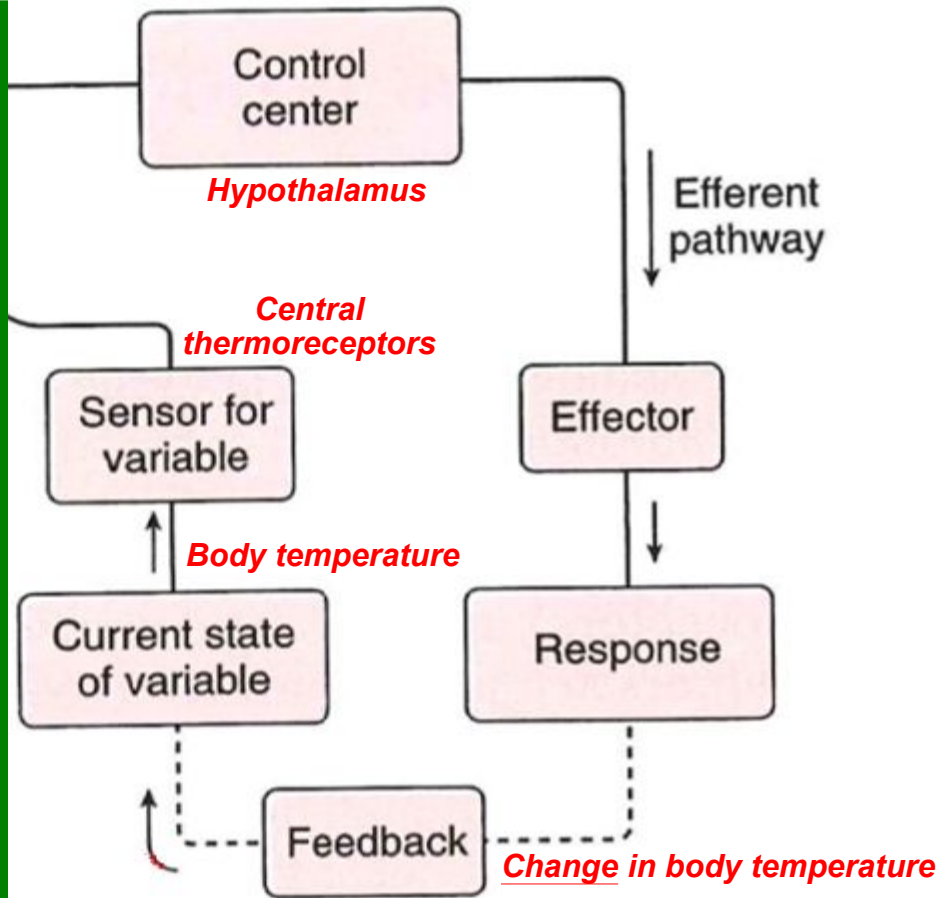
- *Proactive – prompt the system to act before the changes begin to affect it*

Feedforward Control

- Variation of “**other variable**” directly compensates the **anticipated** changes in the controlled variable (independent of a sensor for the controlled variable)

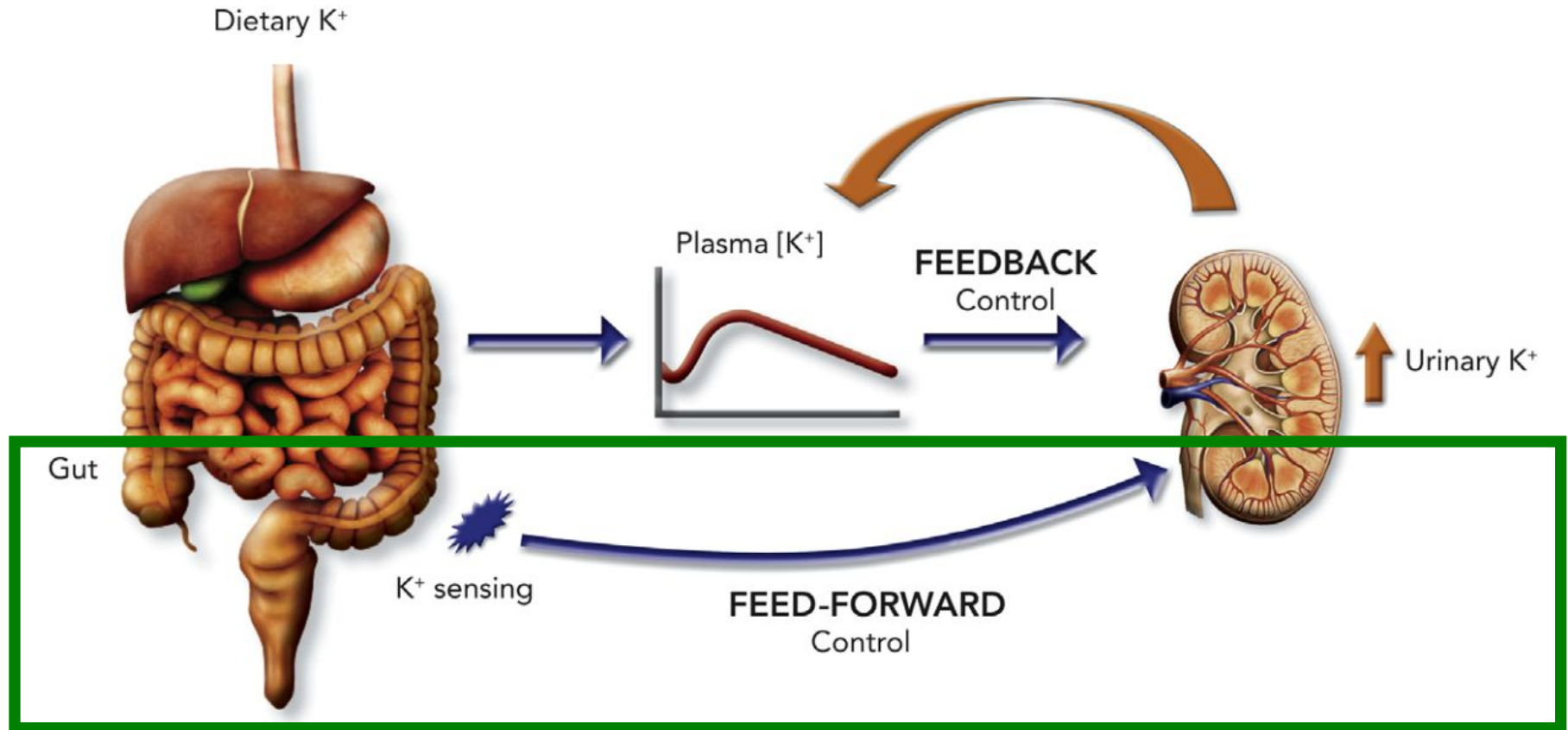


Feedforward



Negative feedback

Example: Blood potassium level

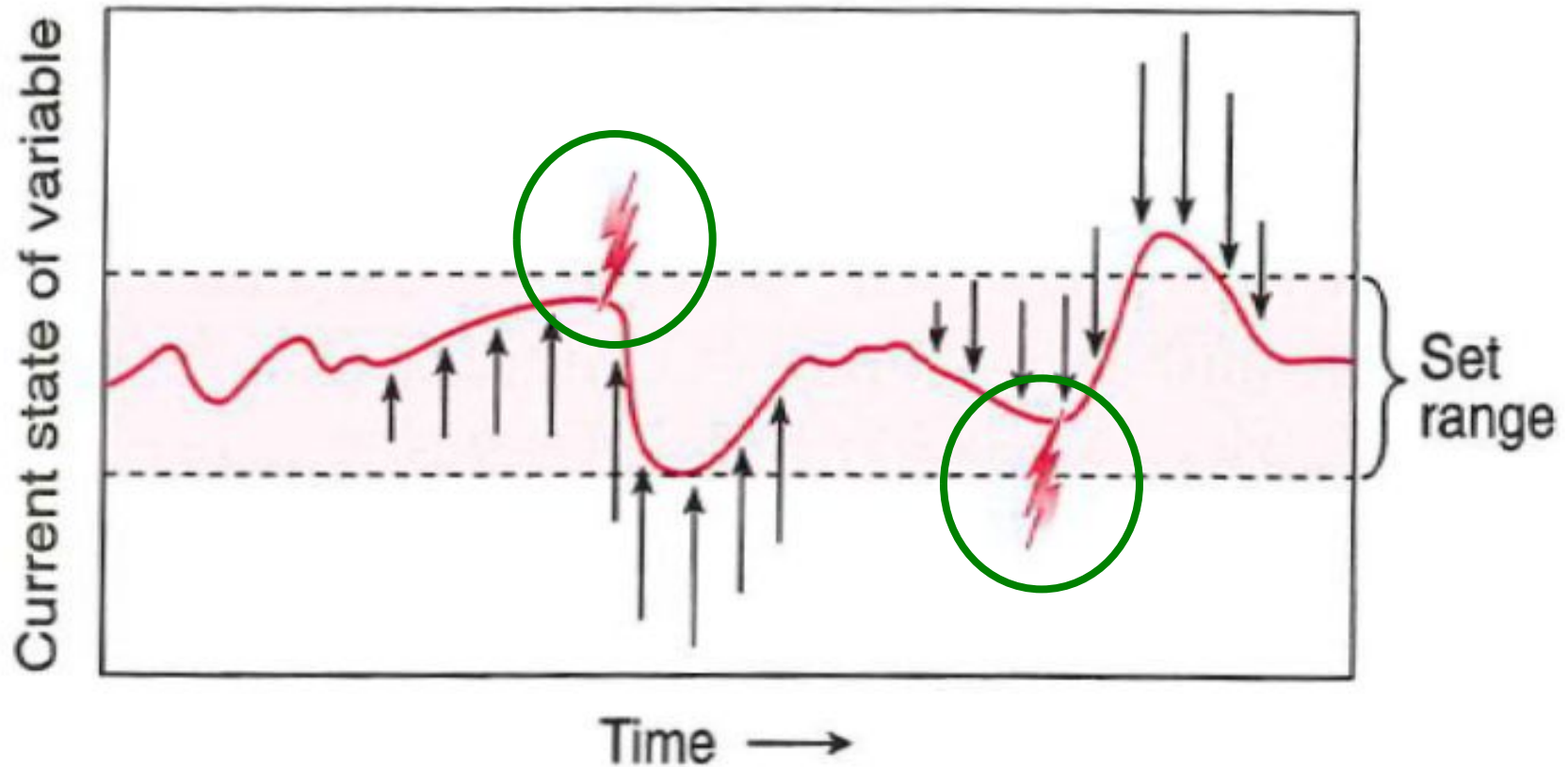


Dietary potassium is sensed by potassium sensors in the **gastrointestinal tract** in the absence of changes in **plasma** potassium

New therapeutic strategy for hyperkalaemia ?

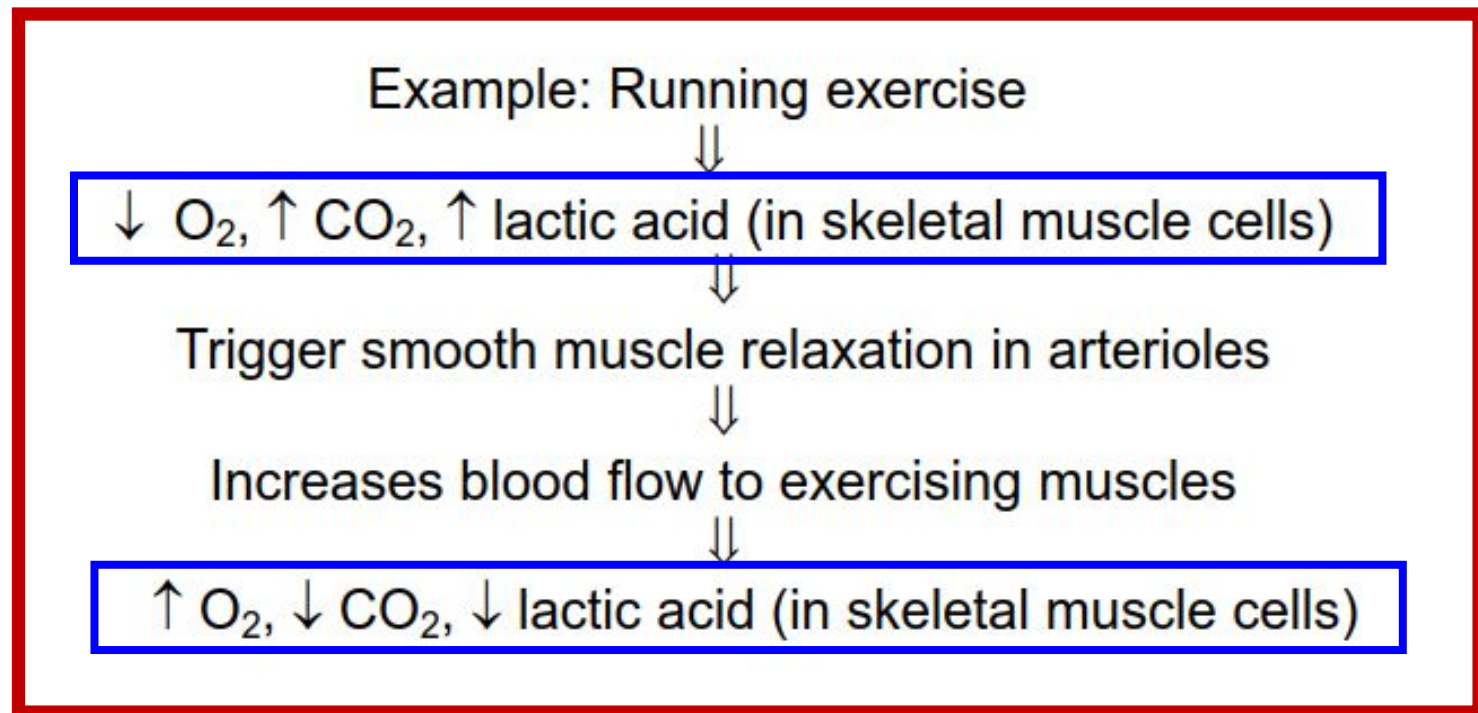
Feedforward Control

Sensor anticipates changes → prompt the system to act in advance

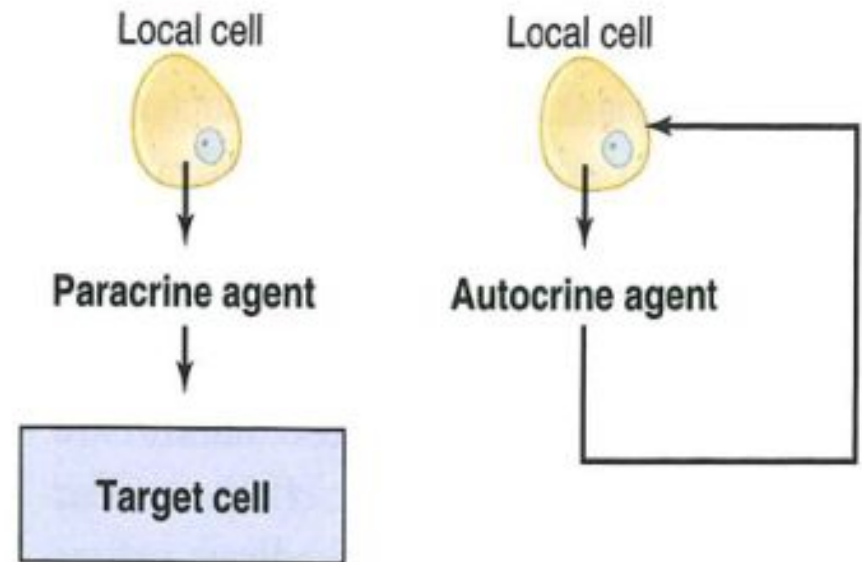
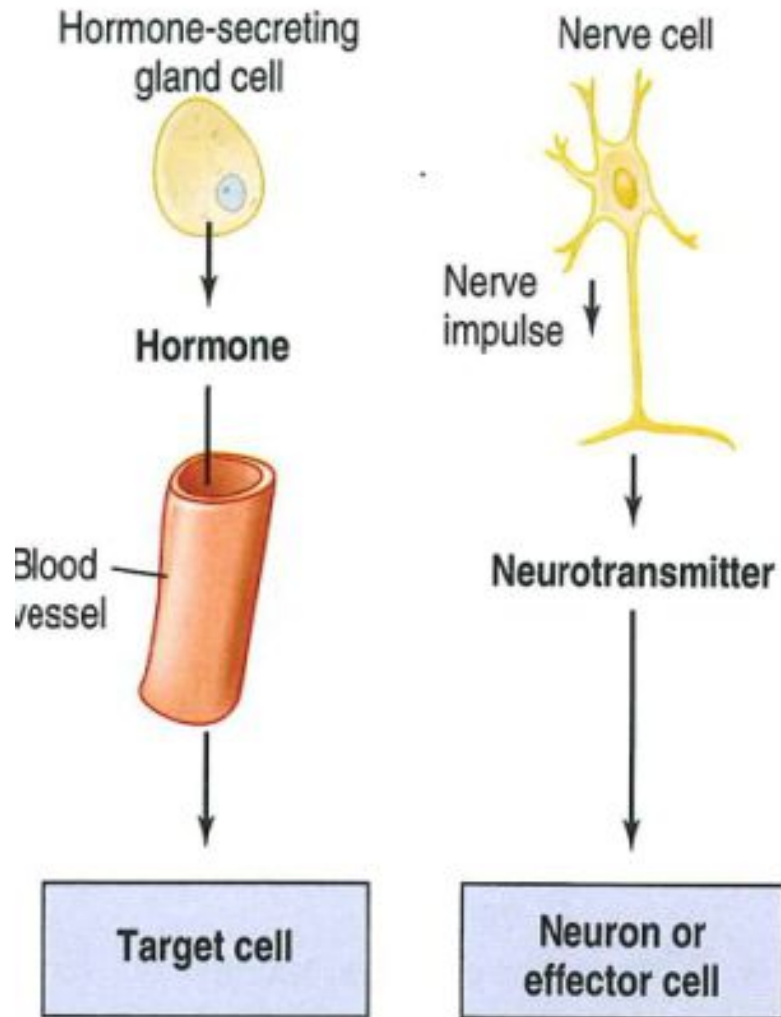


Local Homeostatic Responses

- Some homeostatic responses are highly localized
- Stimulus-response sequences occur only in area of stimulus
- Neither nerves nor hormones are involved



Chemical Messengers in Homeostatic Regulation



Health & Illness

Health

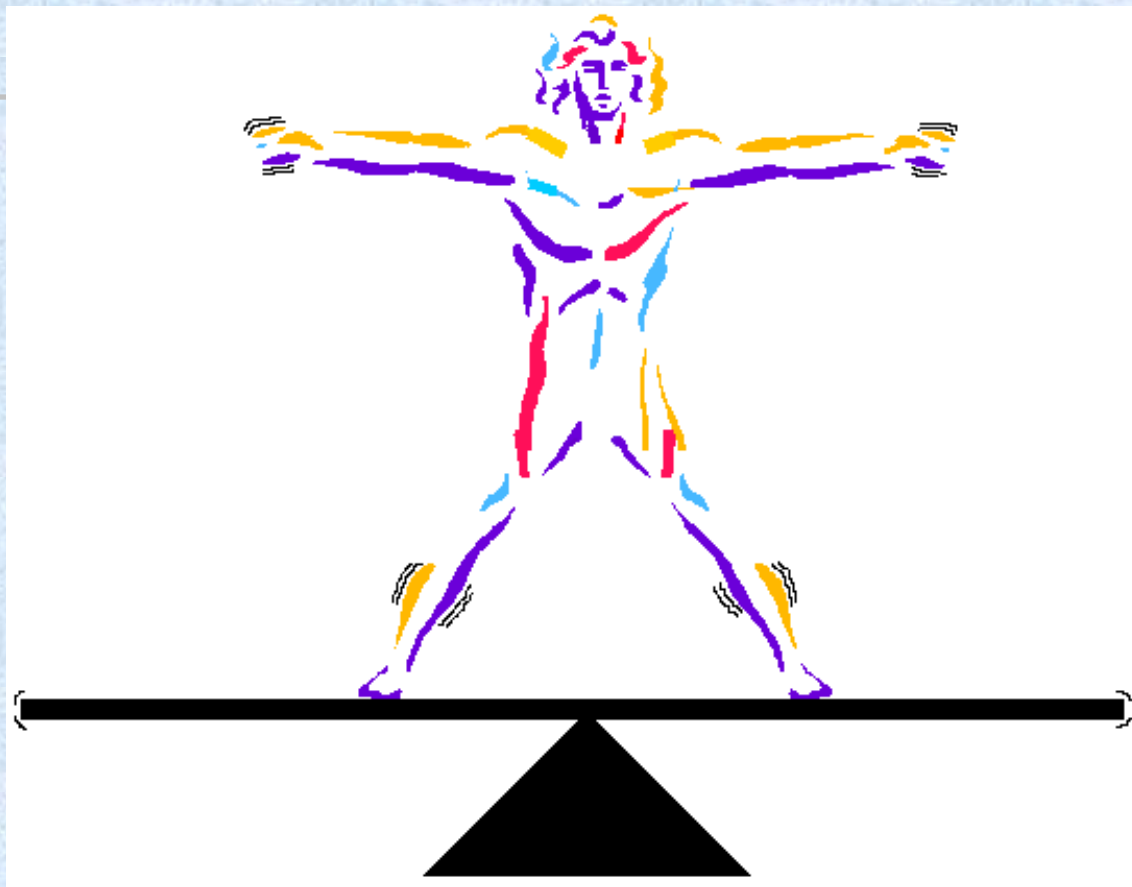
- Body in homeostasis
 - Normal functioning of homeostatic components

Illness

- Body in homeostatic imbalance
 - Failure of normal functioning of homeostatic components

- **Receptors fail** to respond adequately to changes
- **Homeostatic control centers**
 - **fail** to analyze sensory information
 - **fail** to analyze sensory information correctly
 - **fail** to send correct information to effectors
- **Effectors fail** to respond to corrective directions from control centers

Healthcare intervention aims to re-establish patient's homeostasis





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