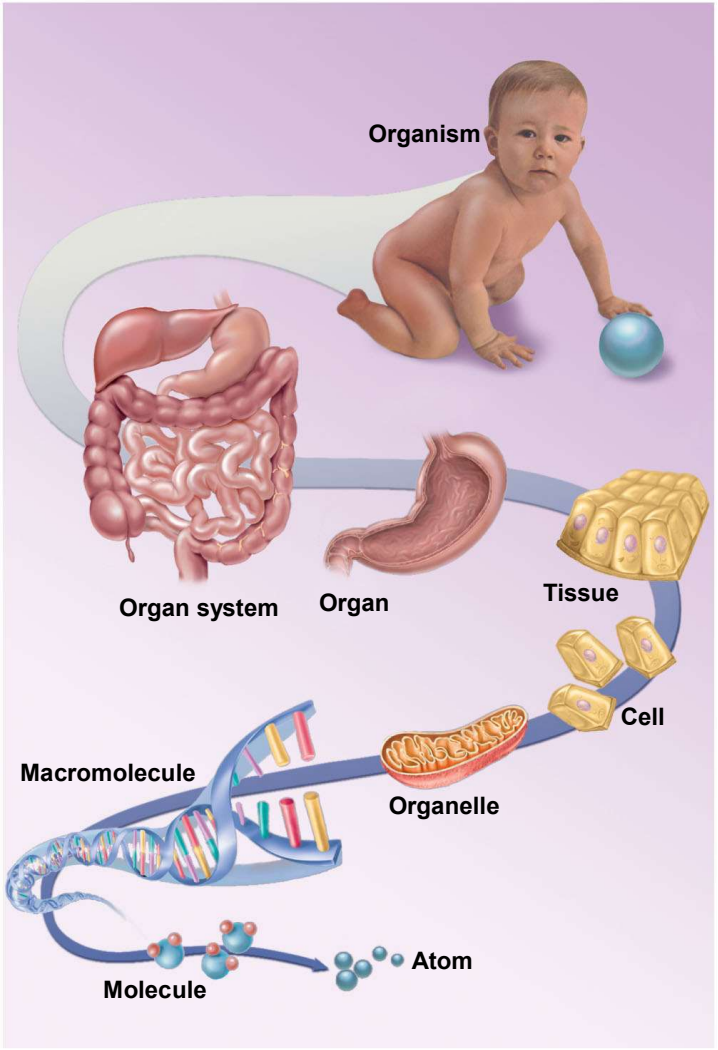
HOMEOSTASIS

Hierarchy of Complexity

- **Organism** is composed of **organ systems**
- **Organ Systems** composed of **organs**
- **Organs** composed of **tissues**
- **Tissues** composed of **cells**
- **Cells** composed of **organelles**
- **Organelles** composed of **macromolecules**
- **Macromolecules composed of molecules**
- **Molecules** composed of **atoms**

The internal enviornment is the immediate space around our cells. This space is where cells must find their nutrients and into which cells Must secrete their waste.



Homeostasis

- How can homeostasis help us understand something as complicated as the Human Body?
  - Human body consist of 50 trillion cells
  - All cells have something in common
    - Need nutrients to grow, repair, and replace themselves
    - Create toxic waste products

Homeostasis

- What is the definition of homeostasis?

- Homeostasis is the tendency toward a relatively stable equilibrium between interdependent elements

- Especially as maintained by physiological processes.

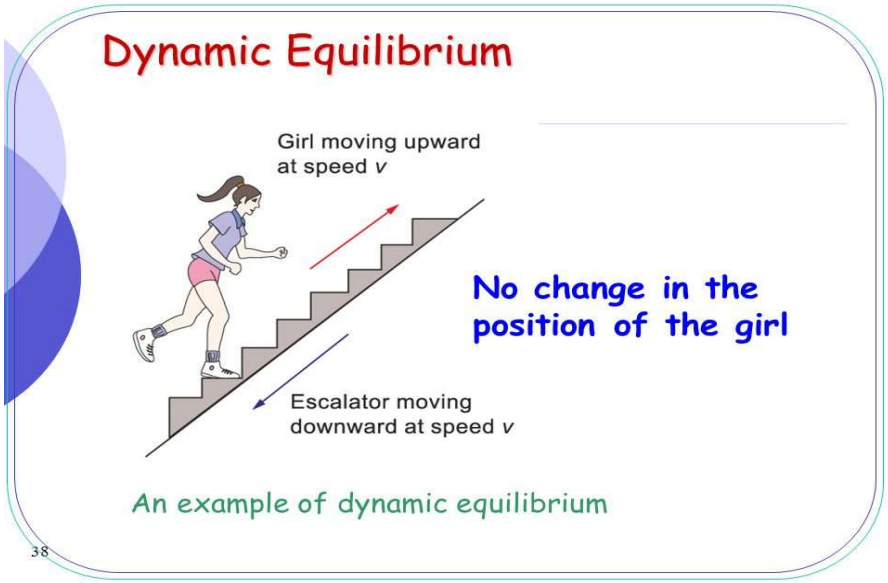
Homeostasis

Claude Bernard (1813-78)

- Observed the constant internal conditions of the body regardless of external conditions
- Thermoregulation /// internal body temperature ranges from 97 to 99 degrees F (38 C) despite variations in external temperatures

Walter Cannon (1871-1945)

- Coined the term '**Homeostasis**'
- Introduced the idea of a **dynamic equilibrium around** a **set point**
- **Negative feedback mechanisms** keeps variable close to the set point

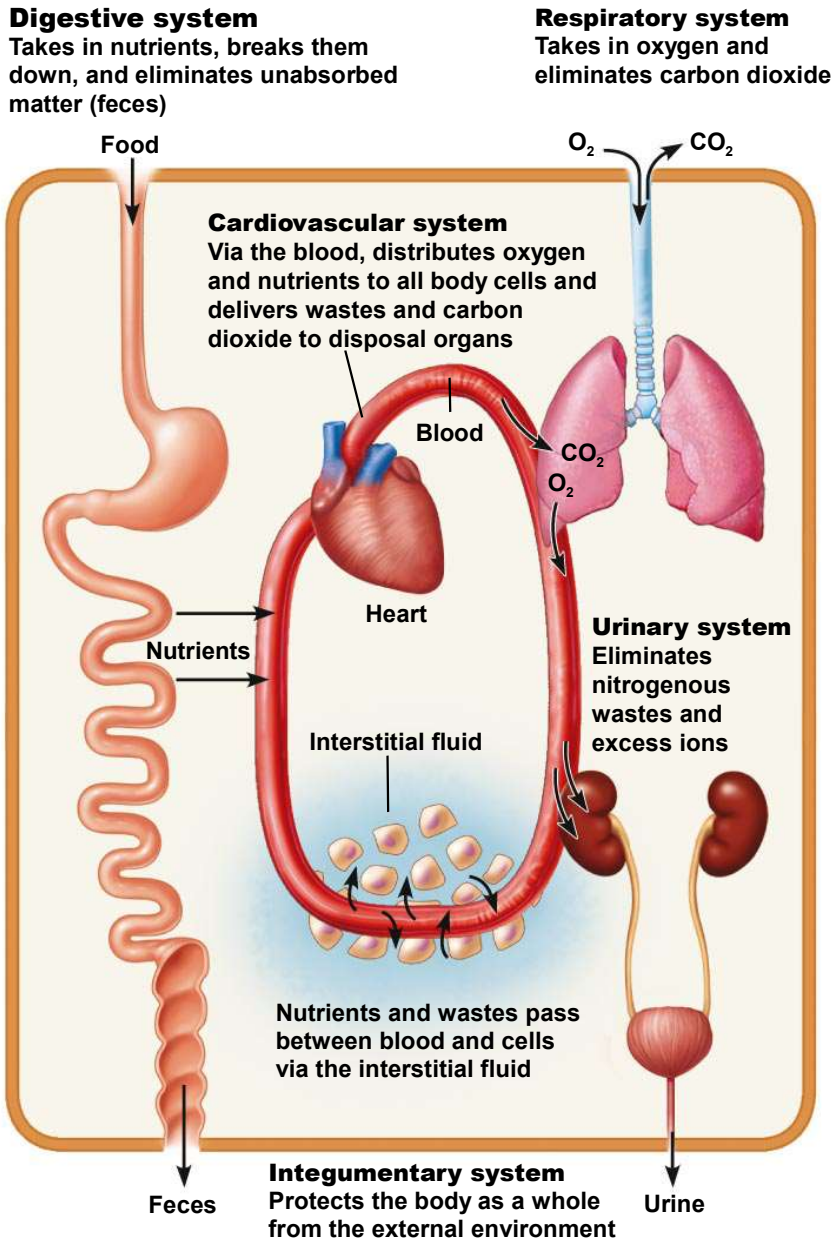


The Relationship Between Our Organ Systems and the Internal-Environment

Human body consist of 11 organ systems

- Integument System (Skin)
- Skeletal System
- Muscular System
- Nervous System
- Endocrine System
- Cardiovascular System
- Digestive System
- Urinary System
- Lyphatic System
- Respiratory System
- Reproductive System

Interstitial Fluid = Internal Environment



What Is Regulate?

- Almost everything!
  - Temperature
  - Glucose
  - Growth
  - Ions like sodium, potasium, protons!
  - And thousands of other parts of our physiology

- However, other things are not regulated.
  - e.g. Vitamin D

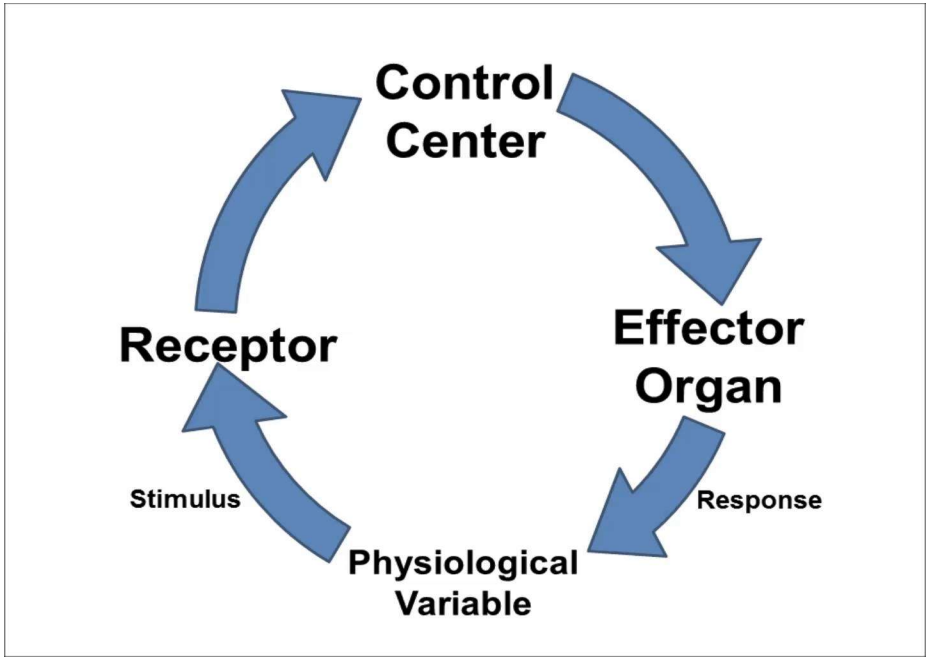
Homeostasis Is Maintained by the Autonomic Nervous System and the Endocrine System

- ANS is a division of your nervous system (electrical & ANS is subconsious)
- Endocrine system (chemical & subconsious)

- The hypothalamus is the “boss” of these two control centers

Homeostasis Uses Feedback Loops

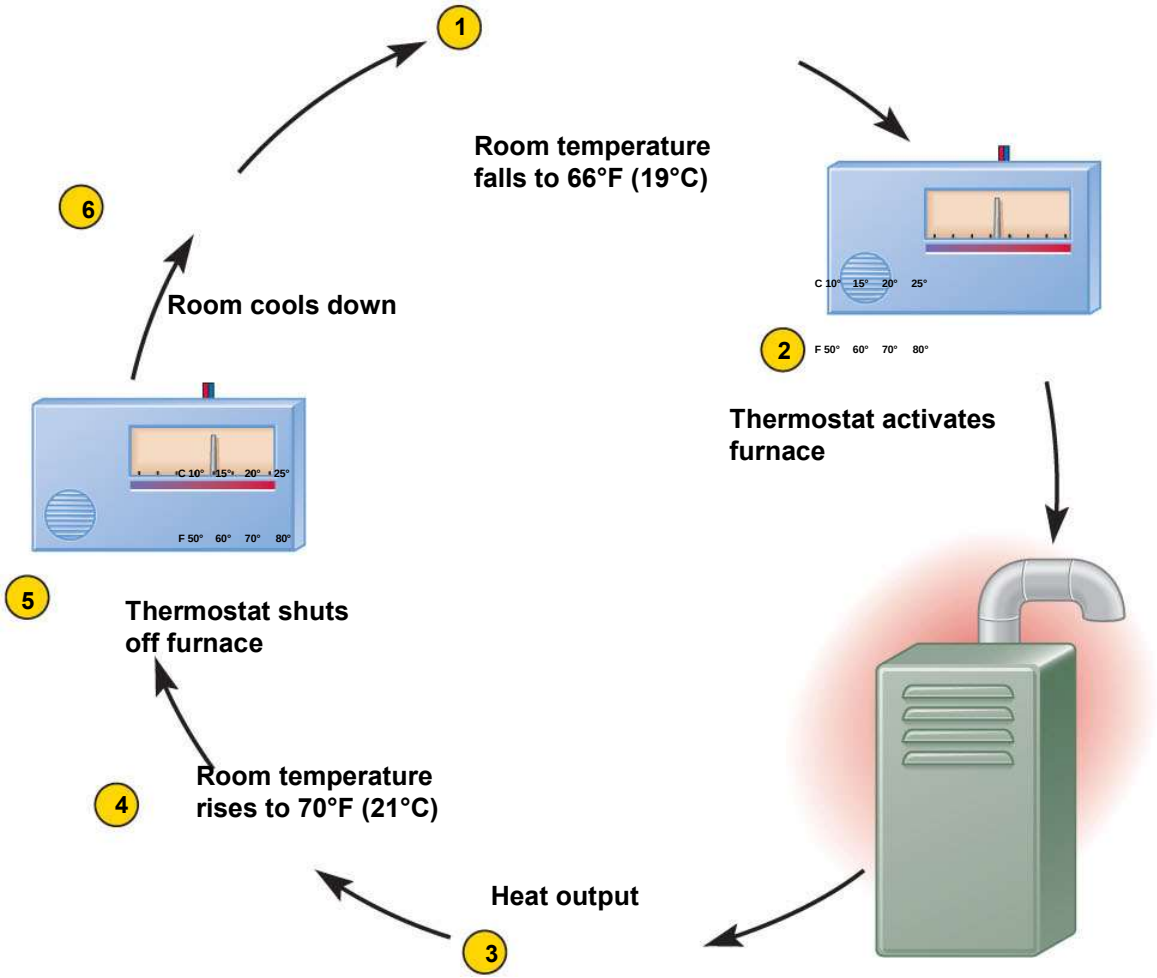
- Positive Feedback Loops
- Negative Feedback Loops
- Both types of loop have three similar components
  - Receptor ----> Control Center ---> Effector



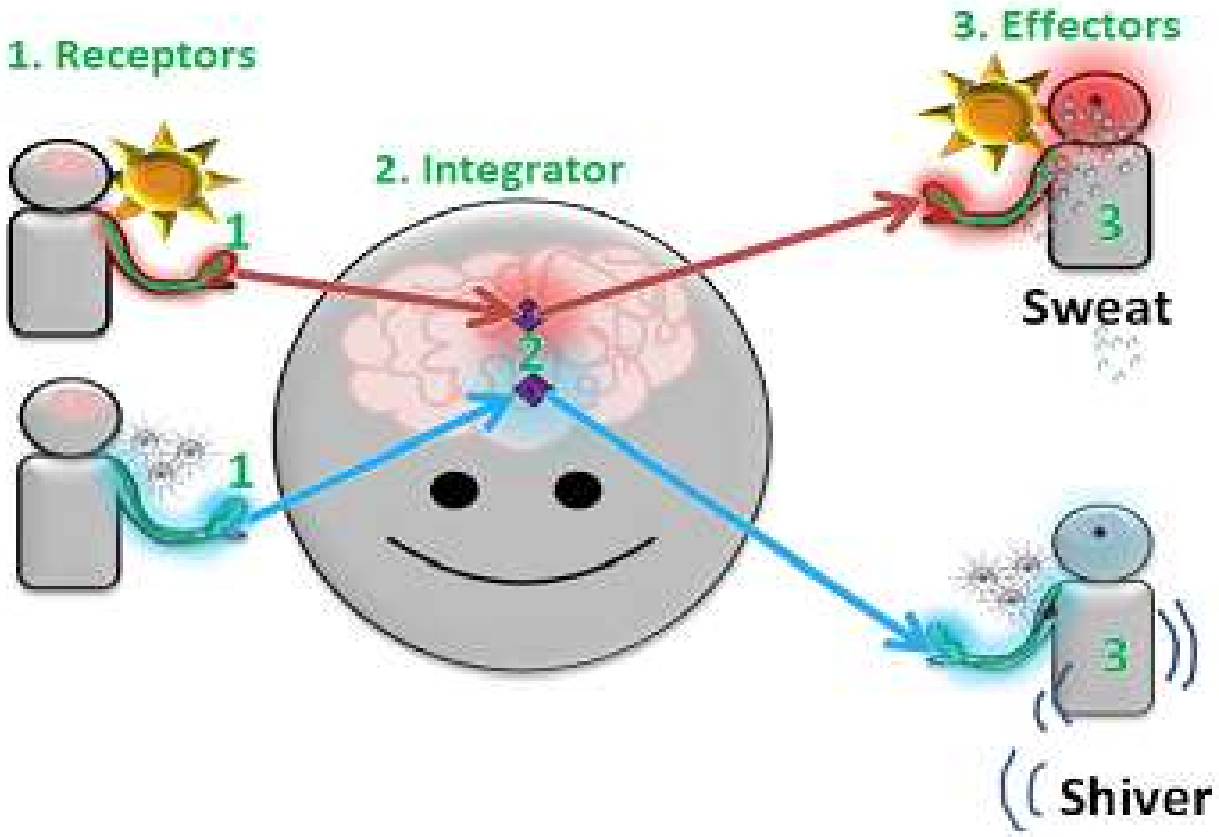
- A stimulus initiates the feedback loop

Negative Feedback and The Furnace Metaphor

Homeostasis = Dynamic Equilibrium

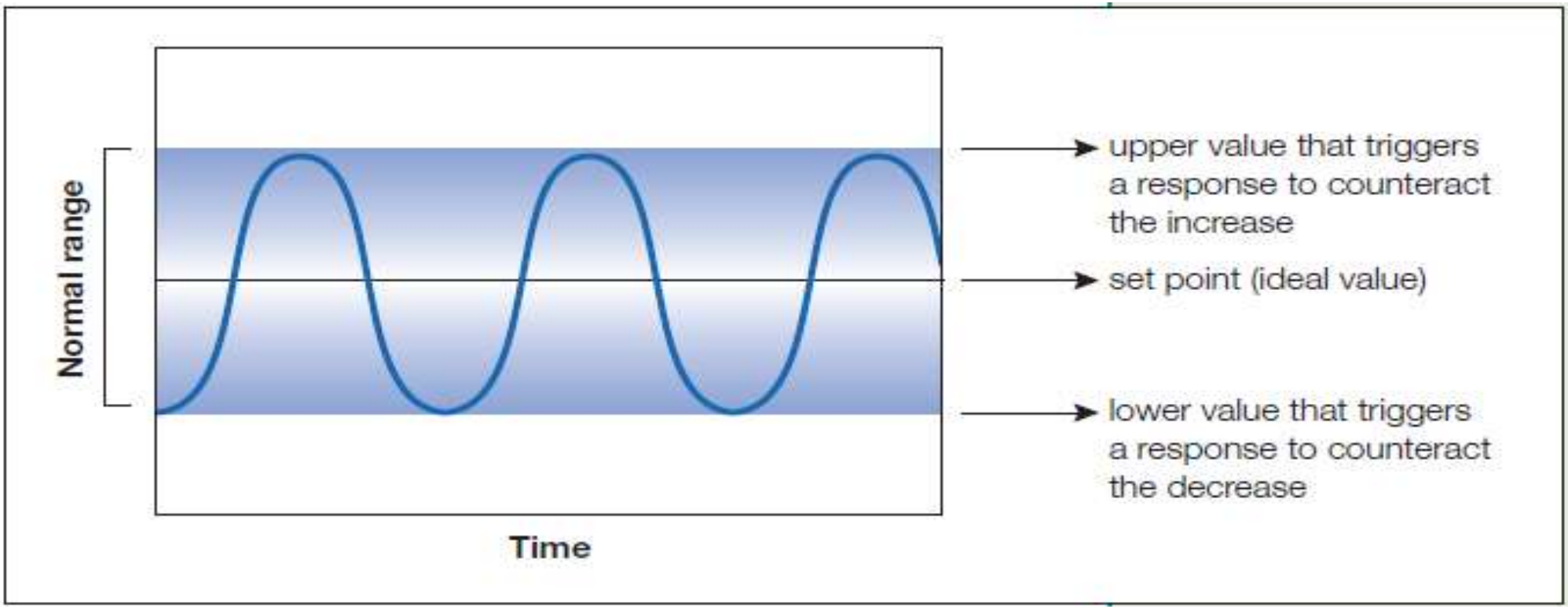


Negative Feedback Loops and Thermoregulation



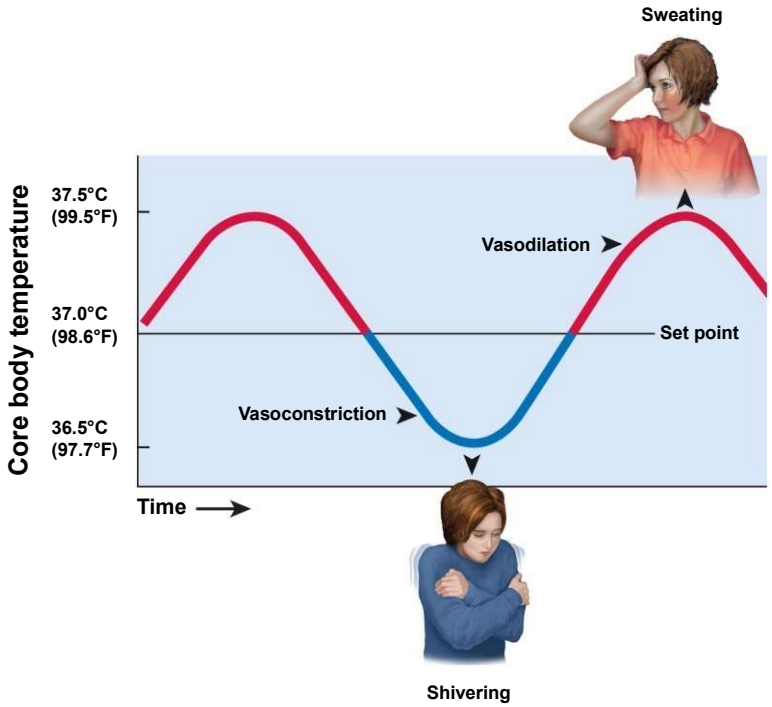
A change in temperature is the stimulus that initiates the negative feedback loop

Negative Feedback



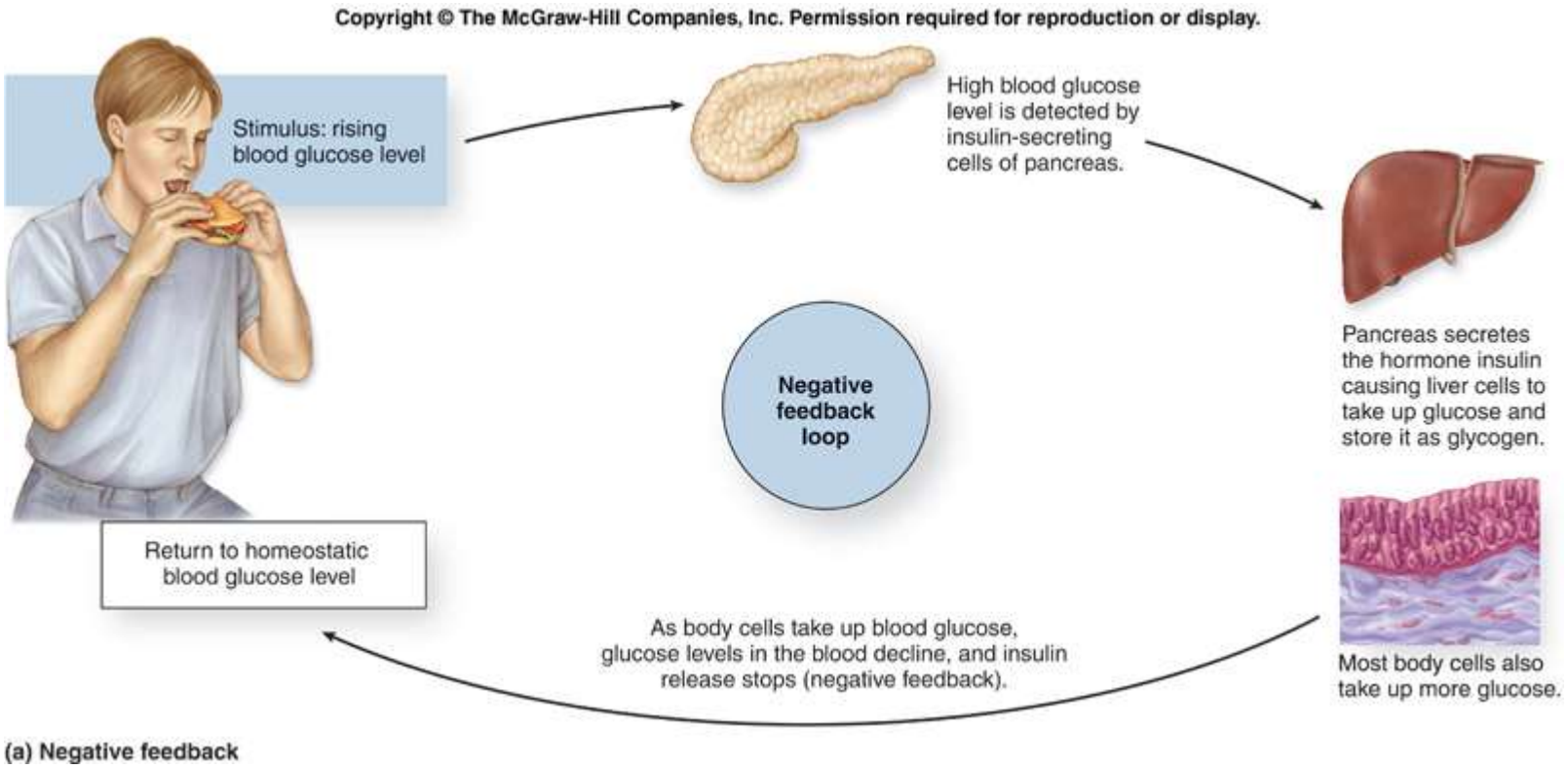
Dynamic Equilibrium

Negative Feedback in Human Thermoregulation



- **Brain senses change in blood temperature**
  - if too warm, vessels dilate in the skin (**vasodilation**) and sweating begins (heat losing mechanisms)
  - if too cold, vessels in the skin constrict (**vasoconstriction**) to conserve heat and shivering begins (heat gaining mechanism)

Negative Feedback Loop



Positive Feedback Loops

- Characterized as “self-amplifing” feedback loops

  Stimulus ---> Response ---> Stimulus ---> Response ---> Stimulus ---> Response

- Potentially more dangerous than negative feedback loops

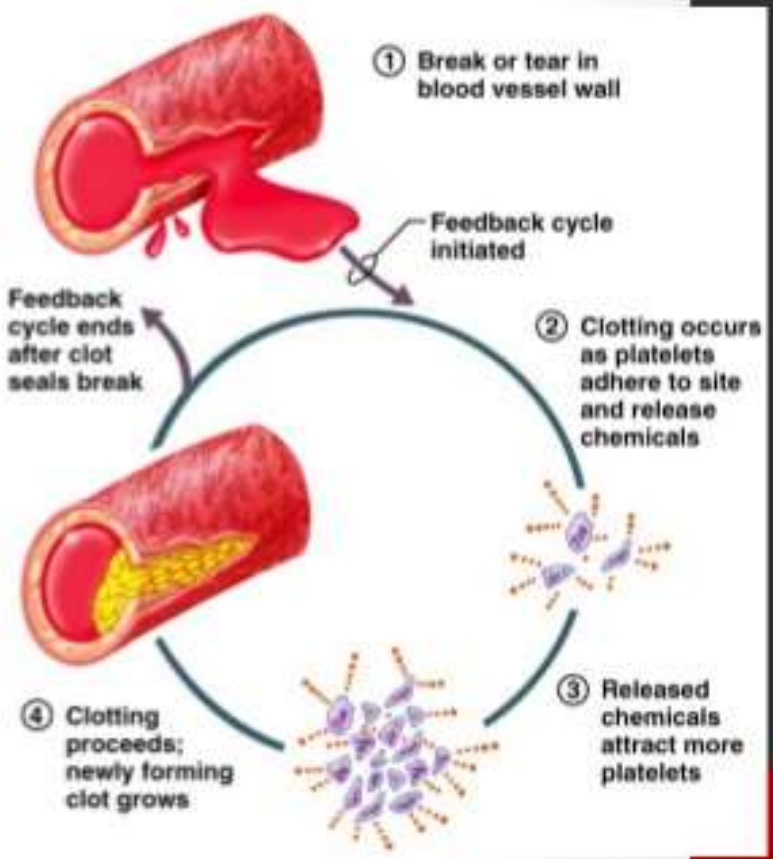
- Fever is a good example of a positive feedback loop

  - A pyrogen resets your “internal thermostat” - you generate more “heat”
  - Higher temp increases rate of “exothermic chemical reactions” in cells
  - Exothermic chemical reactions further increases temperature
  - Now we are trapped in a positive feedback loop
  - Eventually, higher temperatures will denatures proteins and this will cause death

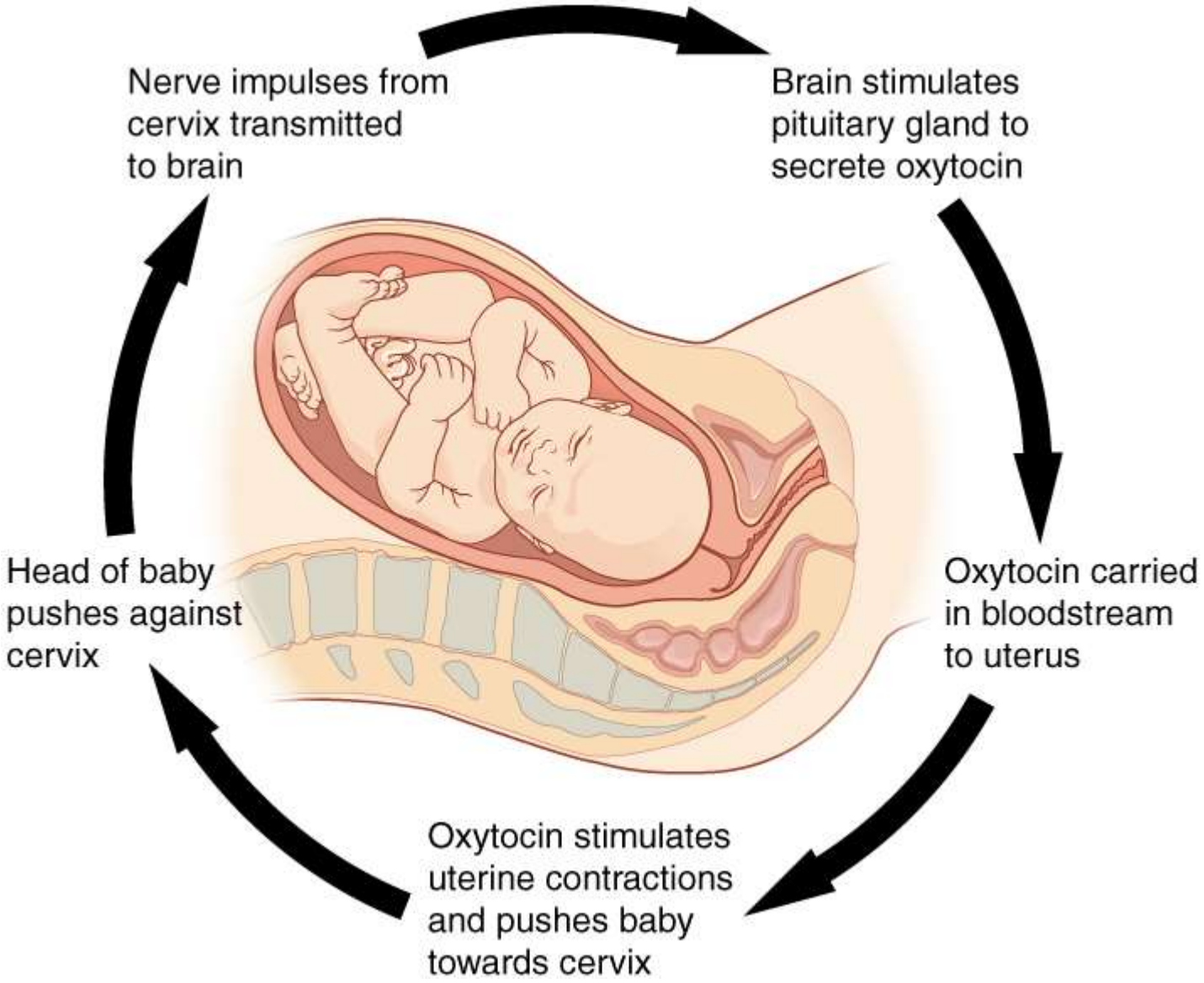
Some Physiologic Conditions Require Positive Feedback Loops

Positive Feedback

- In positive feedback systems, the output enhances or exaggerates the original stimulus
- Example: Regulation of blood clotting



Childbirth = Positive Feedback Loop



Importance of Homeostasis

- To maintain the internal environment of an organisms in a steady and balanced state (i.e. dynamic equilibrium)
- It's necessary in order to establish the optimum conditions of the organism.

Medicine and Homeostasis

- Disease occurs when homeostasis fails

- Doctors apply the principles of homeostasis to understand the cause of the disease

- There is also a direct link between the mind and the body

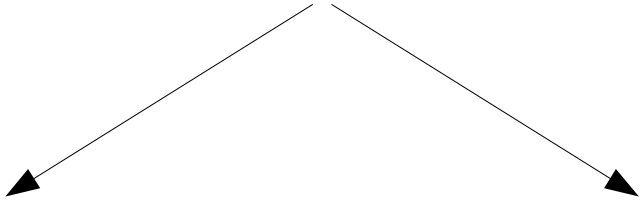
- The conscious brain can be in conflict with the subconscious brain (limbic system)

The Mind-Body Axis
(Stress & Homeostasis)

The Conscious Brain
(Cerebral Cortex)

Our Subconscious Brain
The Paleomammalian Brain
(Limbic System)

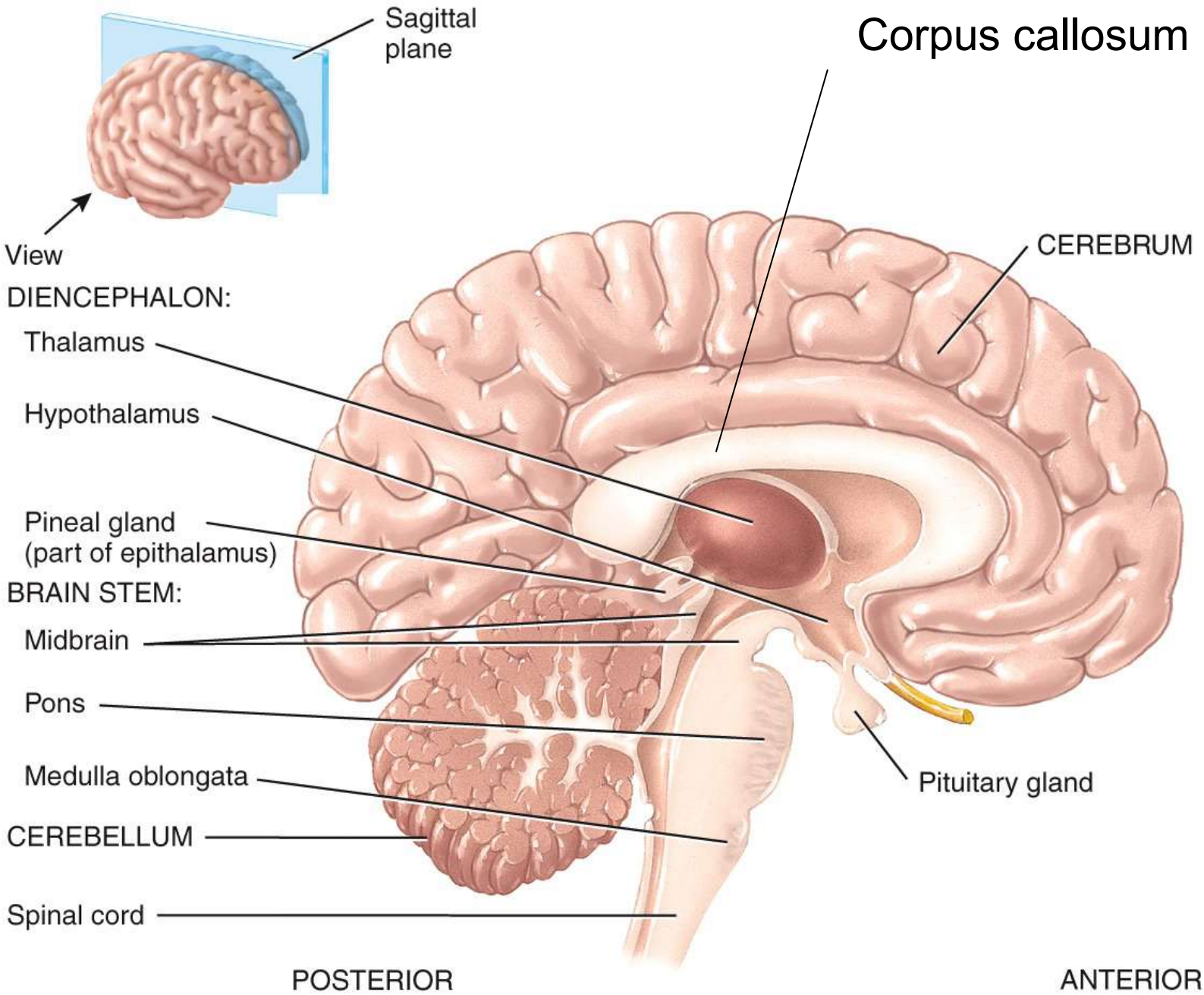
Hypothalamus
(This is the "boss" of both the endocrine system and autonomic nervous system)



Endocrine
System

Autonomic
Nervous System

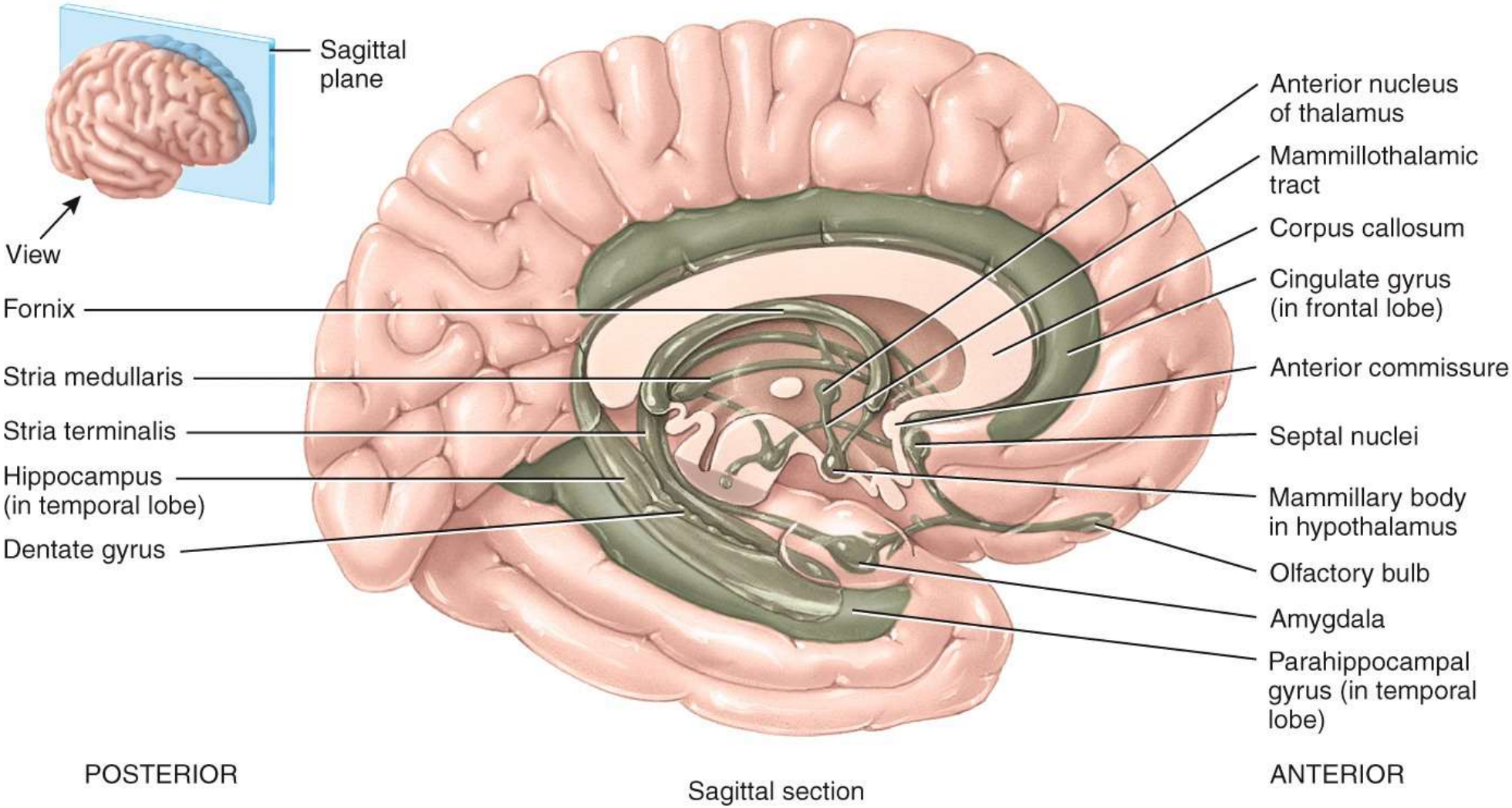
These two systems are used to regulate homeostasis!

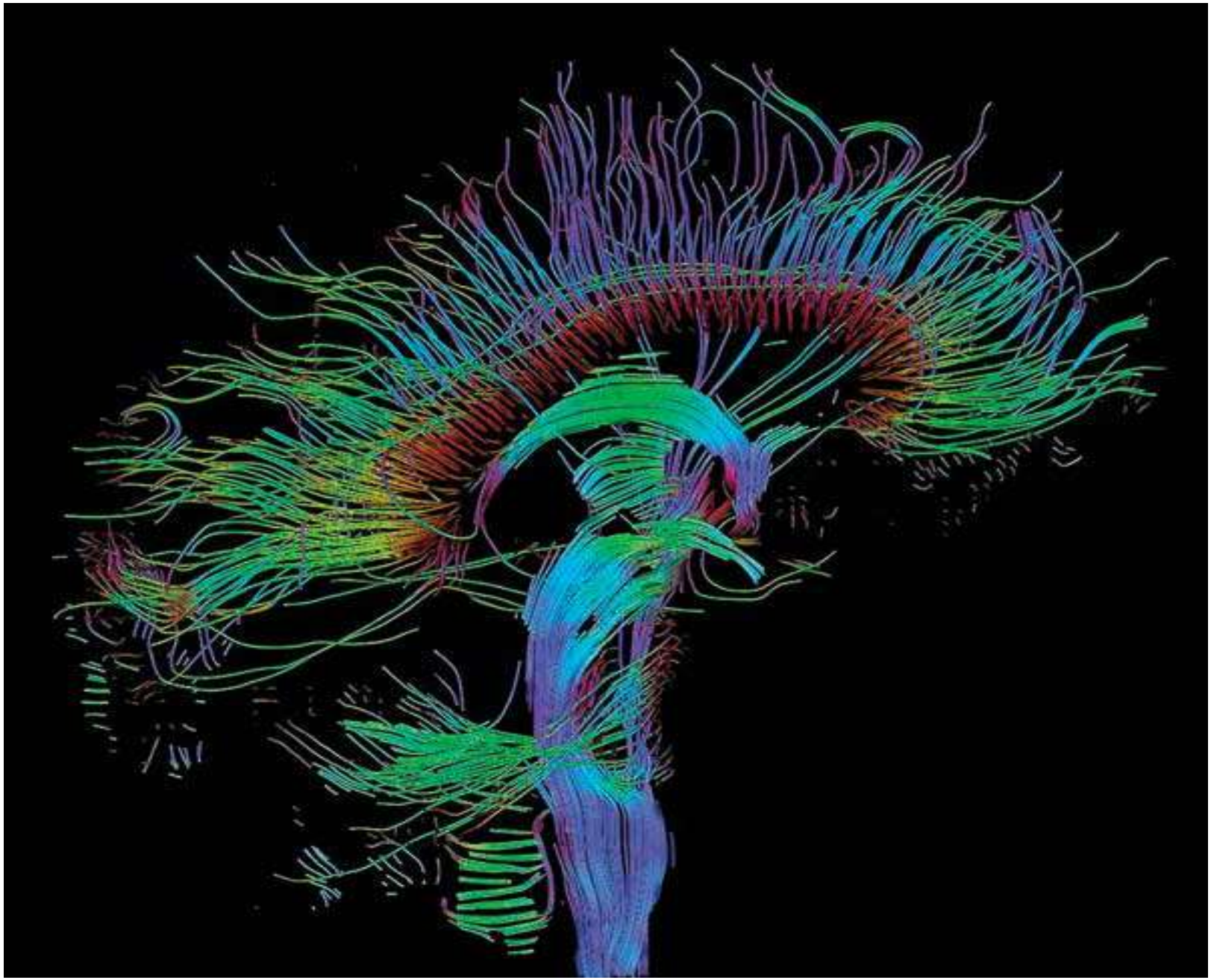


(a) Sagittal section, medial view

The Limbic System

(The Paleo-Mammalian Formation)





The Human Brain

Nerve tracks connect different regions of the brain.

What is stress?

- Stress in not a disease
- Stress in a condition
- Stress is any situation that upsets homeostasis
  - anything that threatens one's physical or emotional well-being
  - e.g. // injury, surgery, infection, intense exercise, pain, grief, depression, anger, etc

- Stress is not a disease but stress makes all diseases worst!

Stress and the General Adaptive Syndrome

- General adaptation syndrome (GAS)
  - consistent way how body always reacts to a stressor
  - typically starts with elevated levels of epinephrine followed by increasing levels of glucocorticoids (especially cortisol)

- GAS occurs in three stages
  - alarm reaction stage
  - resistance stage
  - exhaustion stage

Alarm Reaction

- Initial response to stress mediated by
  - norepinephrine from the sympathetic nervous system & adrenal medulla
  - epinephrine from the adrenal medulla

- Response to “fright” (i.e. panic) and prepares the body to either “fight or flight”
  - stored glycogen is catabolized
  - increase in aldosterone and angiotensin levels
    - angiotensin helps raise blood pressure
    - aldosterone promotes sodium and water conservation

Stage of Resistance

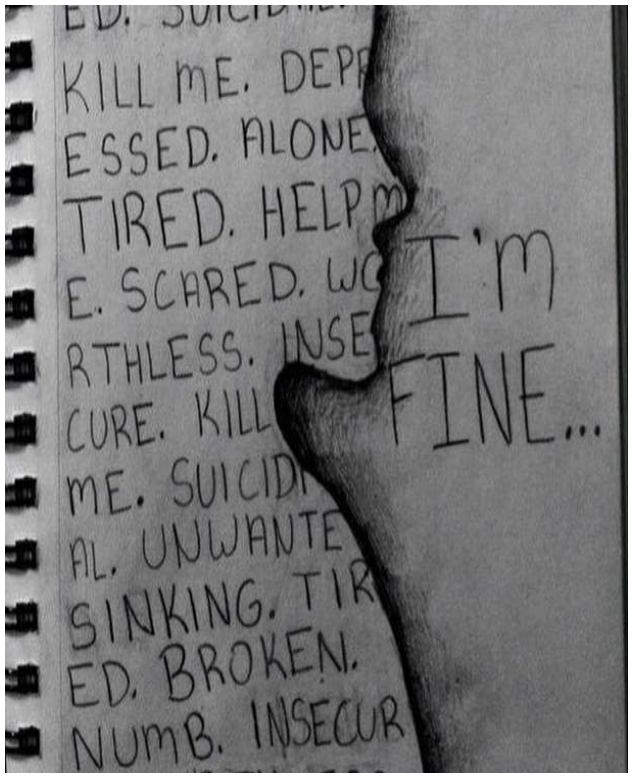
- After a few hours (or days), glycogen reserves are gone (no glucose in storage)
- However, brain needs glucose /// need to provide alternate fuels for metabolism
- Hypothalamus secretes corticotropin-releasing hormone /// causes pituitary to release adrenocorticotropic hormone (ACTH)
- Pituitary secretes increasing amounts of ACTH
  - stimulates the adrenal cortex to secrete cortisol and other glucocorticoids
  - promotes the breakdown of fat and protein
    - glycerol, fatty acids, and amino acids – used for gluconeogenesis
    - need to produce blood glucose for brain and RBCs
    - resistance stage is dominated by cortisol

Stage of Resistance

- Cortisol has glucose-sparing effect
  - inhibits protein synthesis // break down muscle protein & convert protein into glucose (i.e. gluconeogenesis)
  - adverse effects of excessive cortisol
    - depresses immune function
    - increases susceptibility to infection and ulcers
    - lymphoid tissues atrophy, antibody levels drop, and wounds heal poorly
    - repositions fat deposits in body (from limbs to face & back)

Stage of Exhaustion

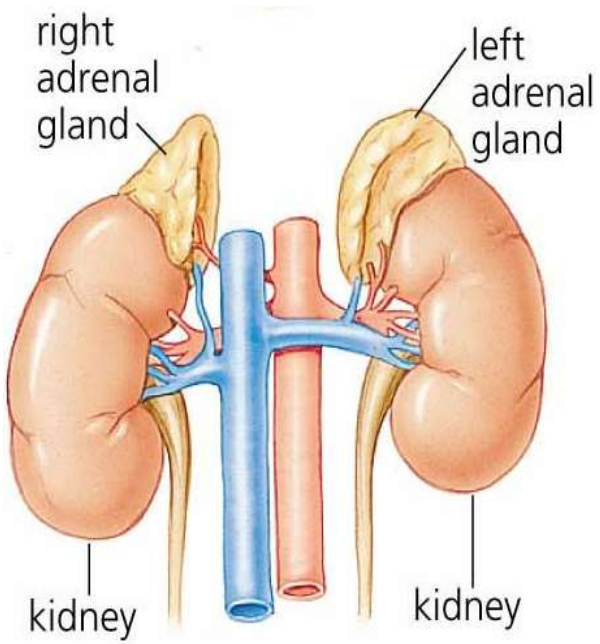
- After stress continues for weeks and/or months
  - fat reserves are gone
  - protein breakdown results in muscle wasting
  - unable to make antibodies = no longer resistant to diseases
  - homeostasis is overwhelmed
  - now physiology marked by rapid decline

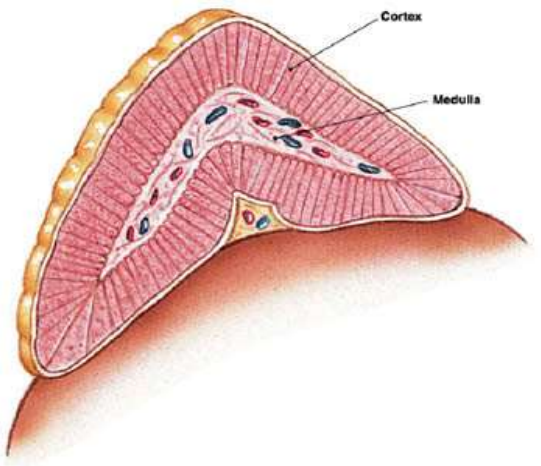


- Furthermore....
  - the loss of glucose homeostasis occurs because adrenal cortex stops producing glucocorticoids
  - however, the adrenal gland continues to produce mineralcorticoids // leads to electrolyte imbalance

Stage of Exhaustion

- Aldosterone continues to promoted water retention and hypertension
  - conserves sodium and hastens elimination of K^+ and H^+
  - hypokalemia and alkalosis will eventually lead to death
  - death results from heart and kidney infection and/or overwhelming infection





You Don't Have to Die From a Broken Heart!

We often hear sadly about a long relationship that ends only after the death of a spouse.

The loss of a love one is a stressor! A period of grieving is normal (resistance stage).

However, this period of grieving may continue for an extended period which then initiates the alarm stage of the GAS

If the individual can not escape from the resistance stage and return to normal homeostasis then the resistance stage will eventually progress into the exhaustion stage with fatal consequences.

So it is important to have someone who can interviene and break the GAS pathway in order to prevent the grieving spouse from “dying from a broken heart”.

Lee Atwater