HOMEOSTASIS and STRESS

Homeostasis

- How can homeostasis help us understand something as complicated as the Human Body?

- The human body consist of 50 trillion cells. But all cells have something in common

    - They need nutrients to grow, repair, and replace themselves (cellular metabolism)

    - The cell's metabolism creates toxic waste products that must be eliminated from body (e.g. carbon dioxide eliminated by lungs)

    - Homeostasis is a systems ability to resist change. In human physiology, homeostasis maintains a stable environment in the fluid surrounding our cells. Nutrients are delivered to the cells and waste products are removed. It is a dynamic state.

Homeostasis

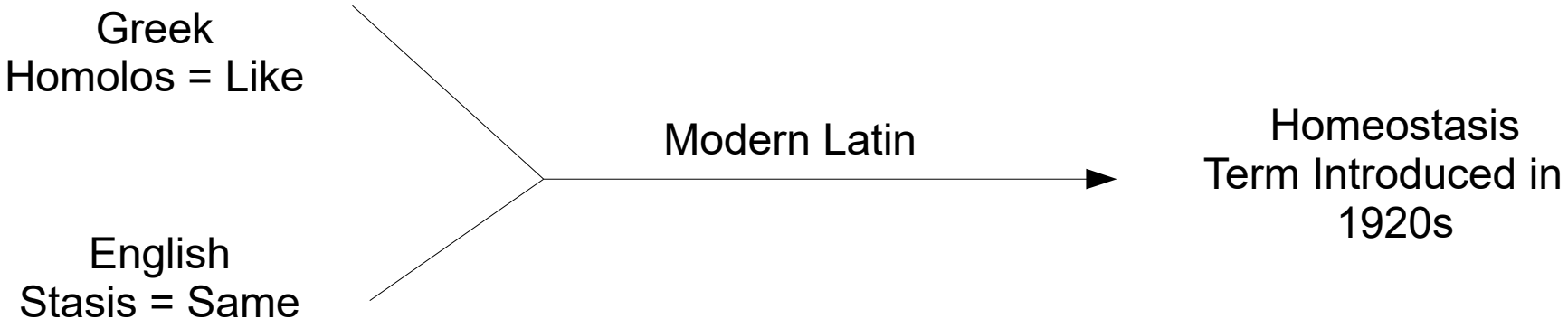
Homeostasis is the ability of a system to resist change. In the human body, our organs function to resist changes in the internal environment. This is the interstitial fluid around our cells.

The interstitial fluid is in a state of dynamic equilibrium. Some organs bring nutrients into the interstitial fluid. These nutrients are transported into the cell's cytoplasm. Cells metabolize the nutrients for growth, repair, or to make new cells.

Cellular metabolism creates toxic waste. Waste products are secreted back into the interstitial fluid. Other organs excrete the waste products from our bodies. Negative and positive feedback mechanisms regulate organs to make homeostasis possible. Disease or death occurs when homeostasis fails.

Homeostasis

- What is the definition of homeostasis? ***It is a systems ability to resist change.***



- Homeostasis is the tendency toward a relatively stable equilibrium in the “internal environment” between cells.

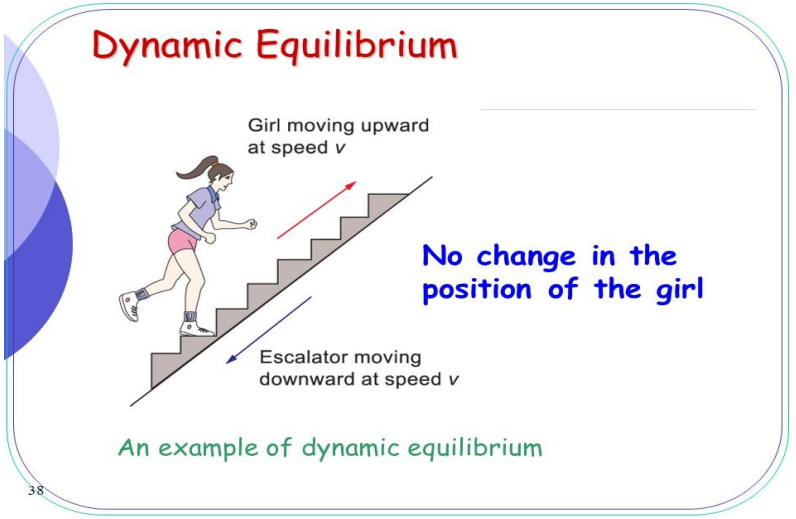
Homeostasis

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

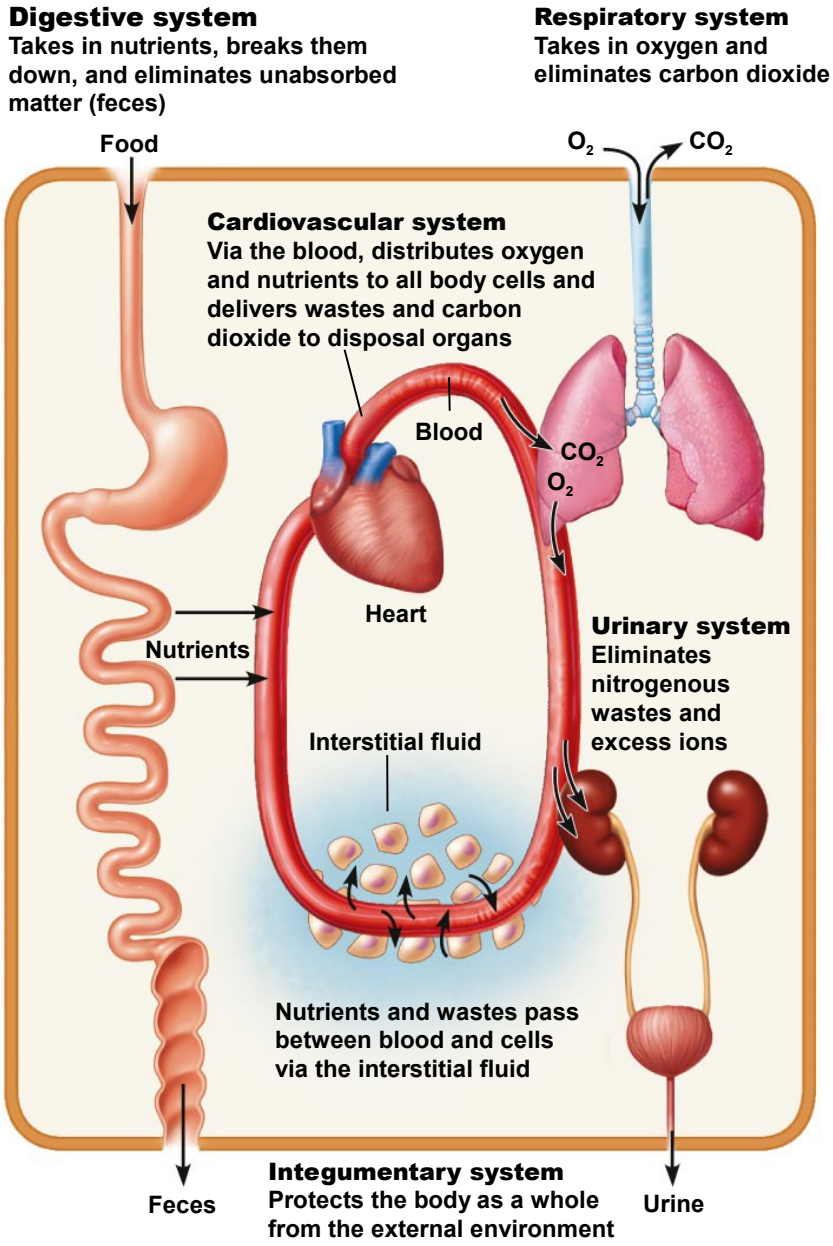


The Relationship Between Our Organ Systems and the Internal-Environment

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 by Homeostasis?

- Almost Everything!
  - Temperature
  - Glucose
  - Growth
  - Ions like sodium, potassium, protons!
  - And many more!

- Somethings are not regulated (e.g. Vitamin D).

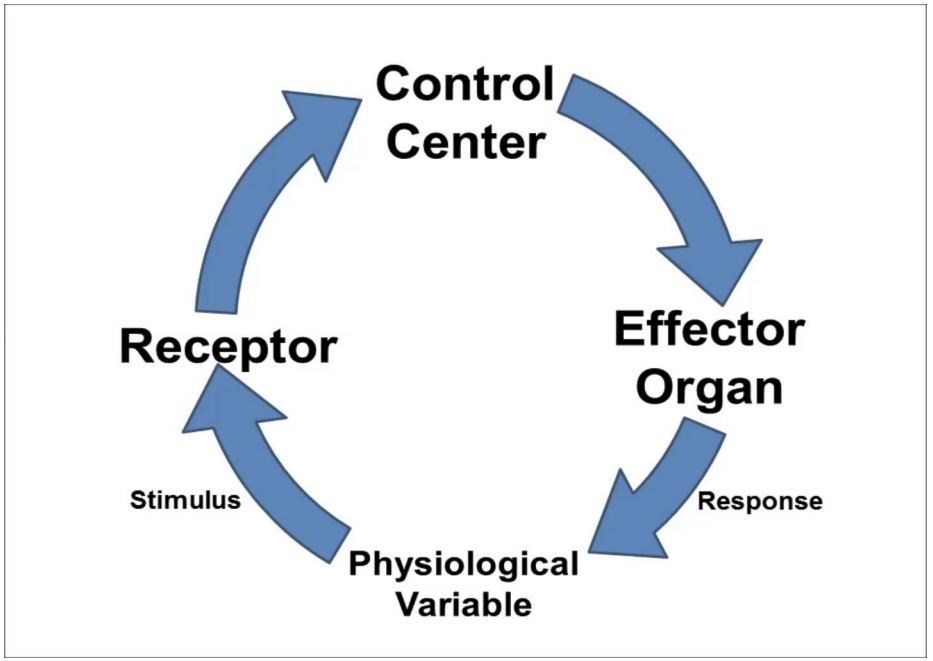
Homeostasis Is Maintained by the Autonomic Nervous System and the Endocrine System

- ANS is a division of your nervous system (not under voluntary control).
- Endocrine system (not under voluntary control).

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

Homeostasis Uses Feedback Loops

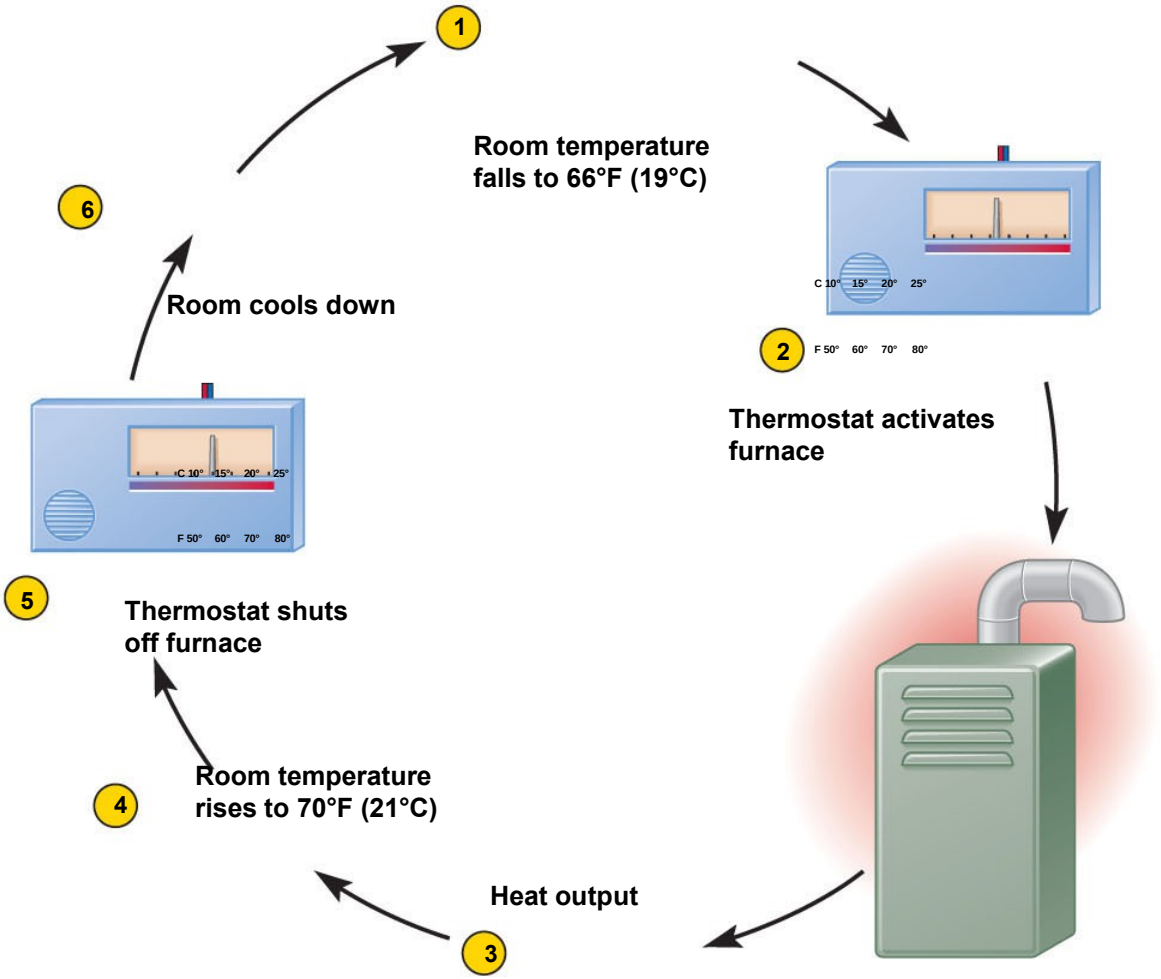
- Positive Feedback Loops
- Negative Feedback Loops
- Both types of loop have three similar components
  - Receptor ----> Control Center ---> Effector



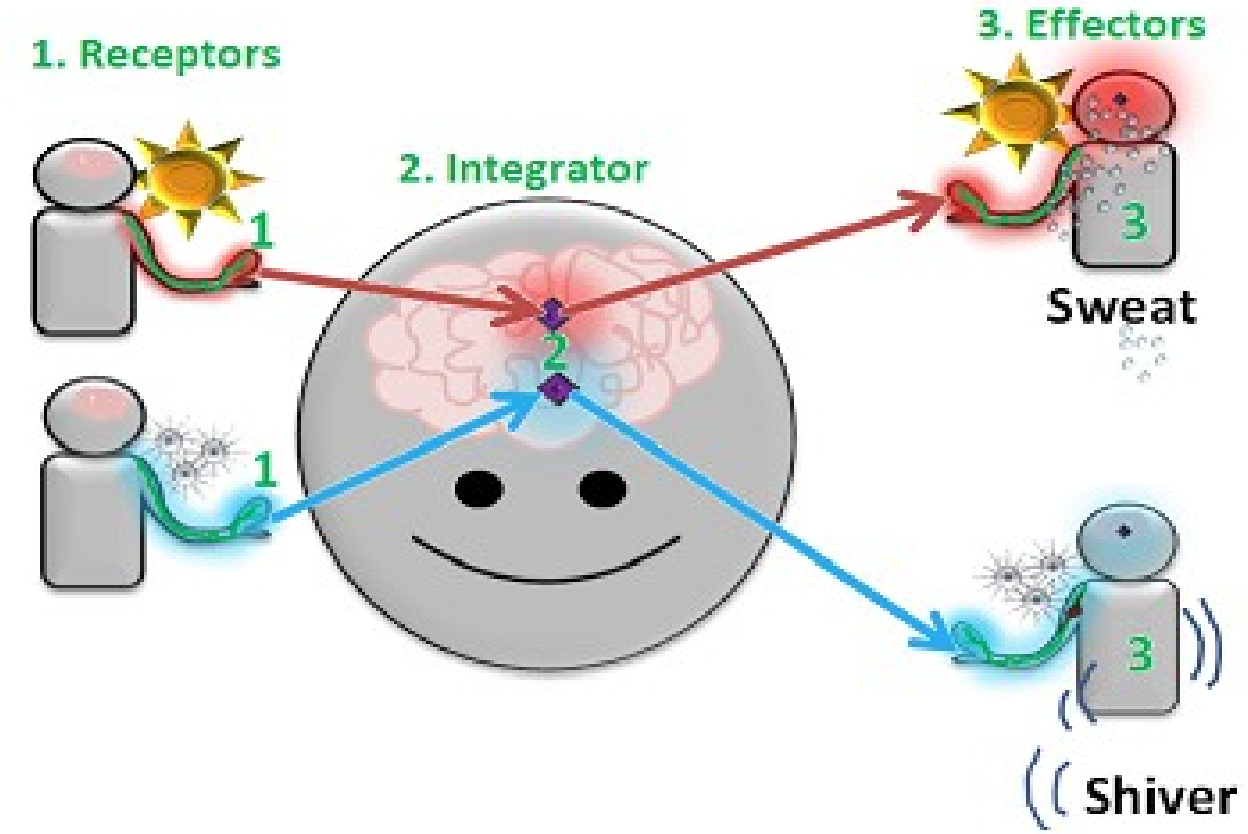
- A stimulus initiates the feedback loop

Negative Feedback and The Furnace Metaphor

Homeostasis = Dynamic Equilibrium

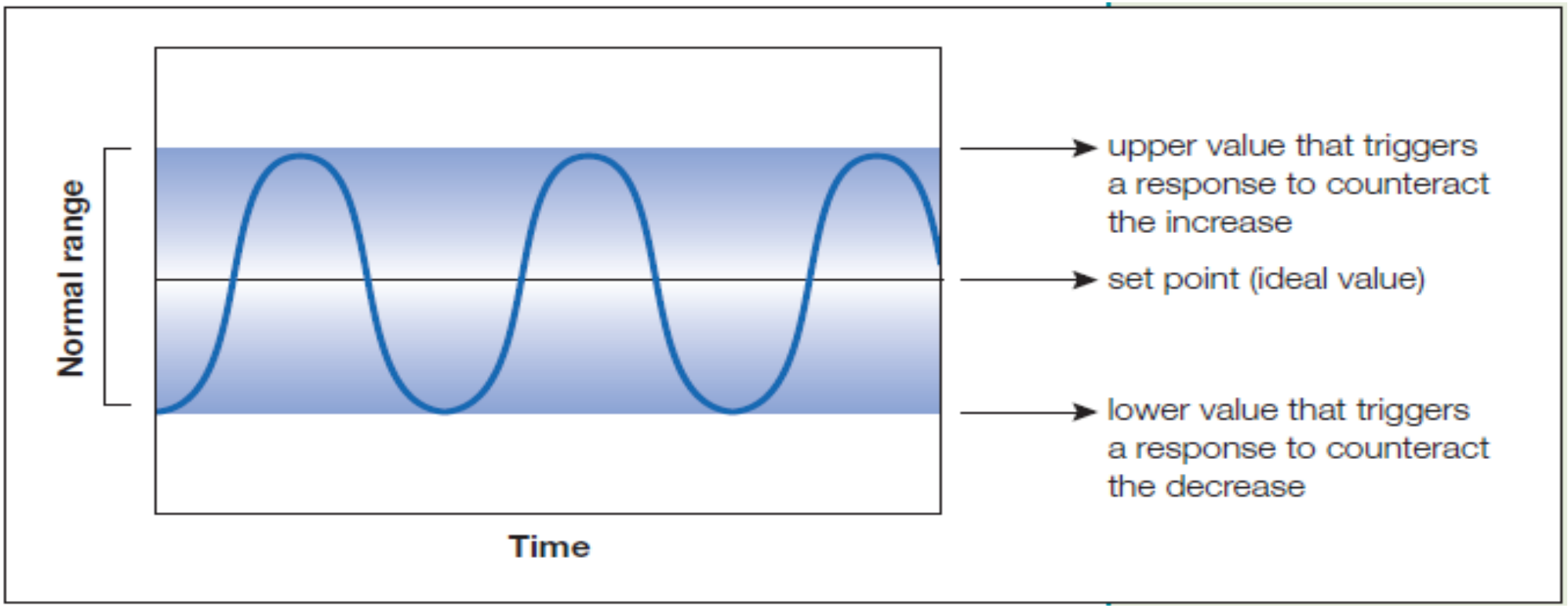


Negative Feedback Loops and Thermoregulation



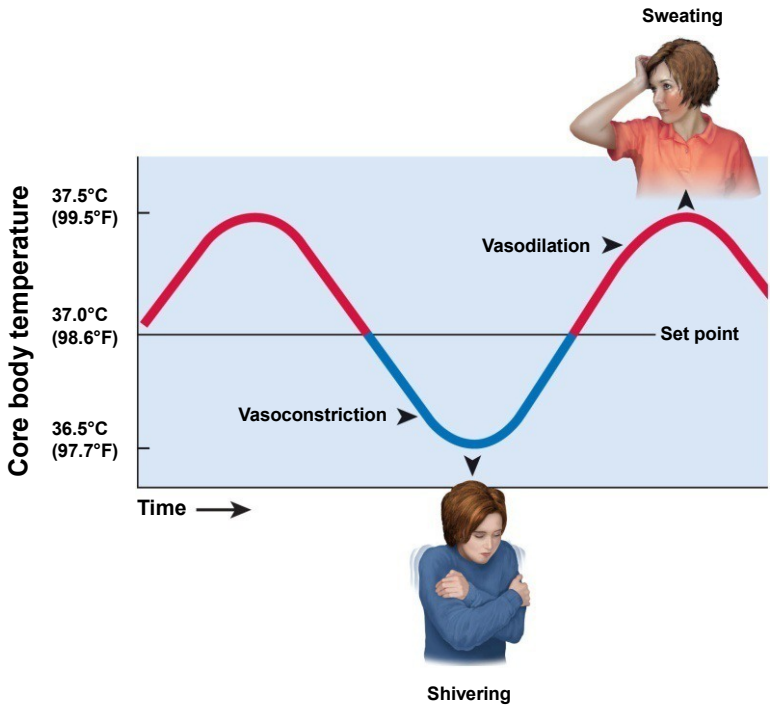
A change in temperature is the stimulus that initiates the negative feedback loop

Negative Feedback



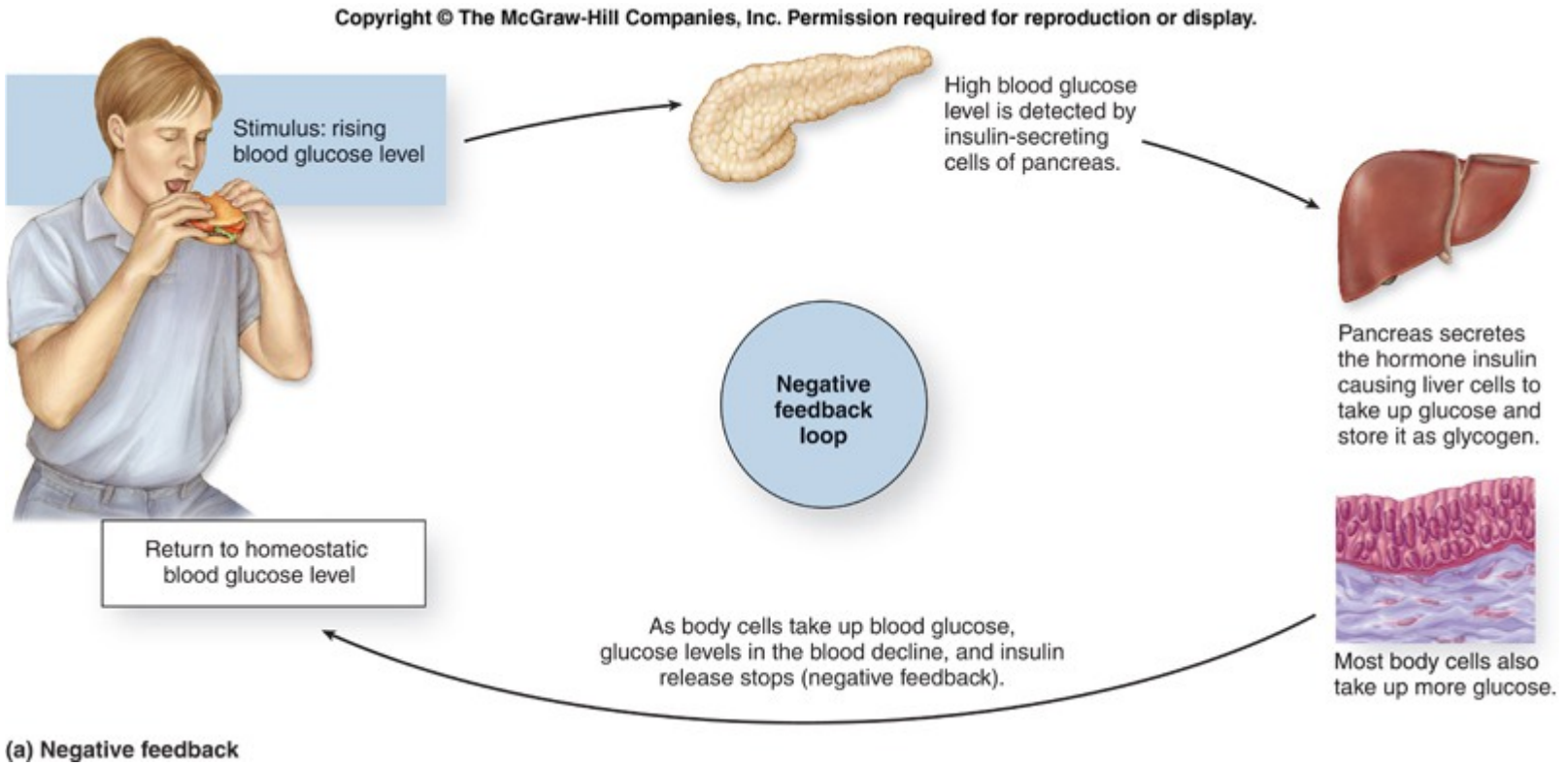
Dynamic Equilibrium

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

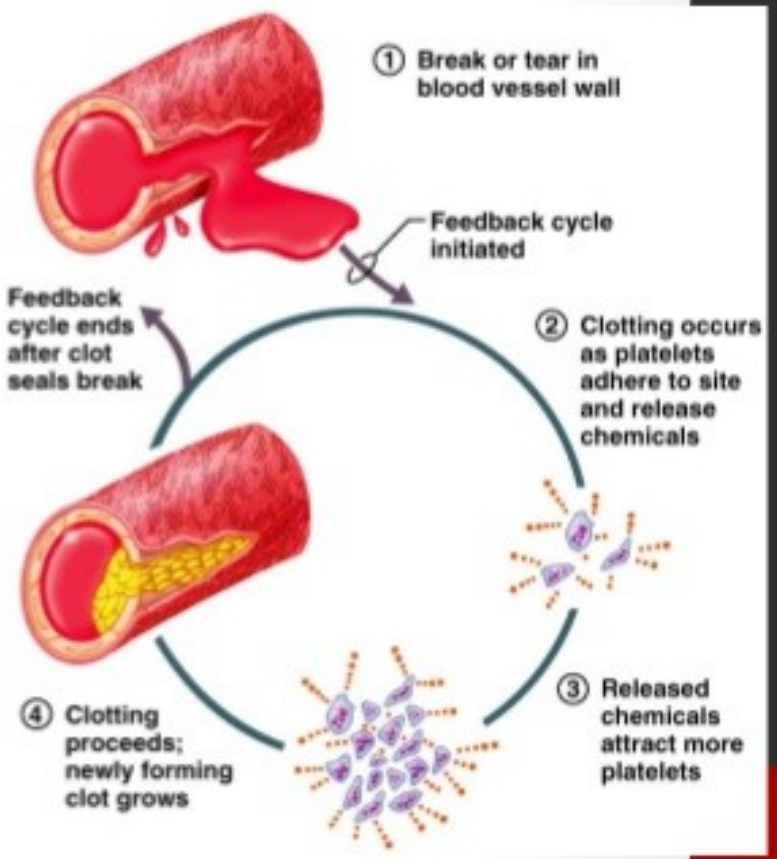
- Fever is a good example of a positive feedback loop

  - 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

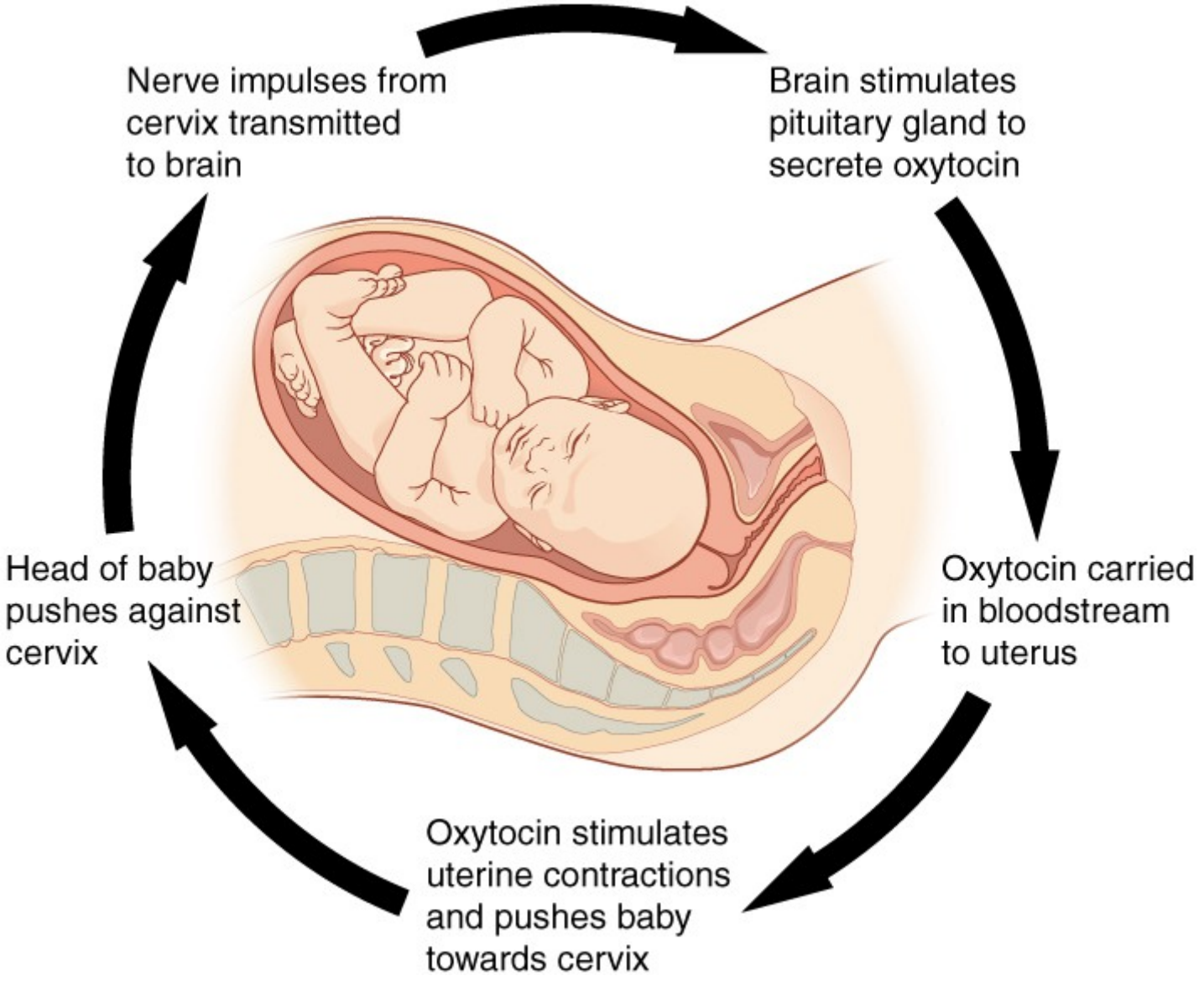
Some Physiologic Conditions Require Positive Feedback Loops

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

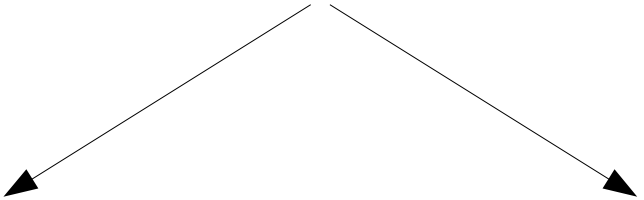
- The conscious brain can be in conflict with the subconscious brain (limbic system)

The Mind-Body Axis
(Stress & Homeostasis)

The Conscious Brain
(Cerebral Cortex)

Our Subconscious Brain
The Paleomammalian Brain
(Limbic System)

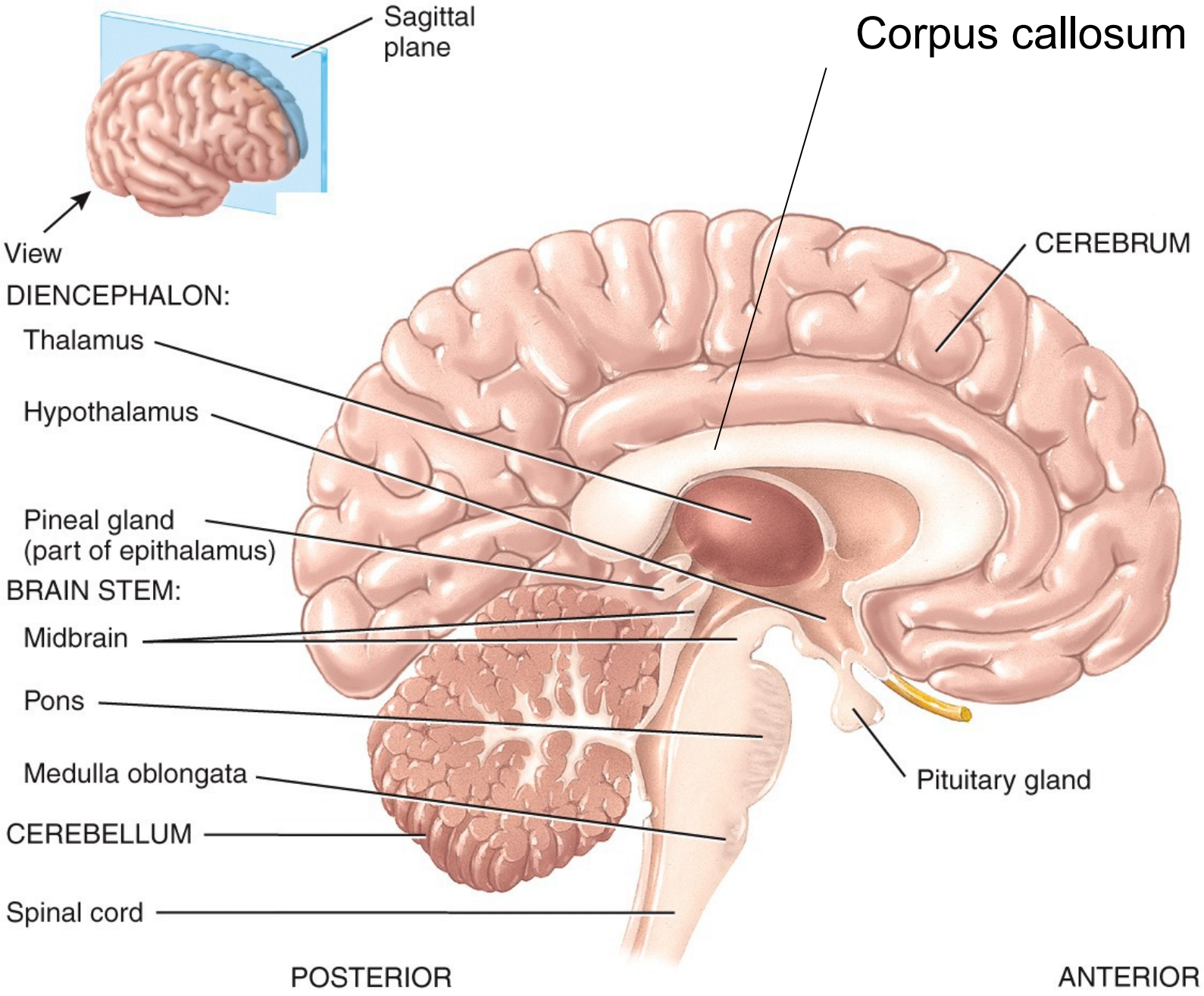
Hypothalamus
(This is the "boss" of both the endocrine system and autonomic nervous system)



Endocrine
System

Autonomic
Nervous System

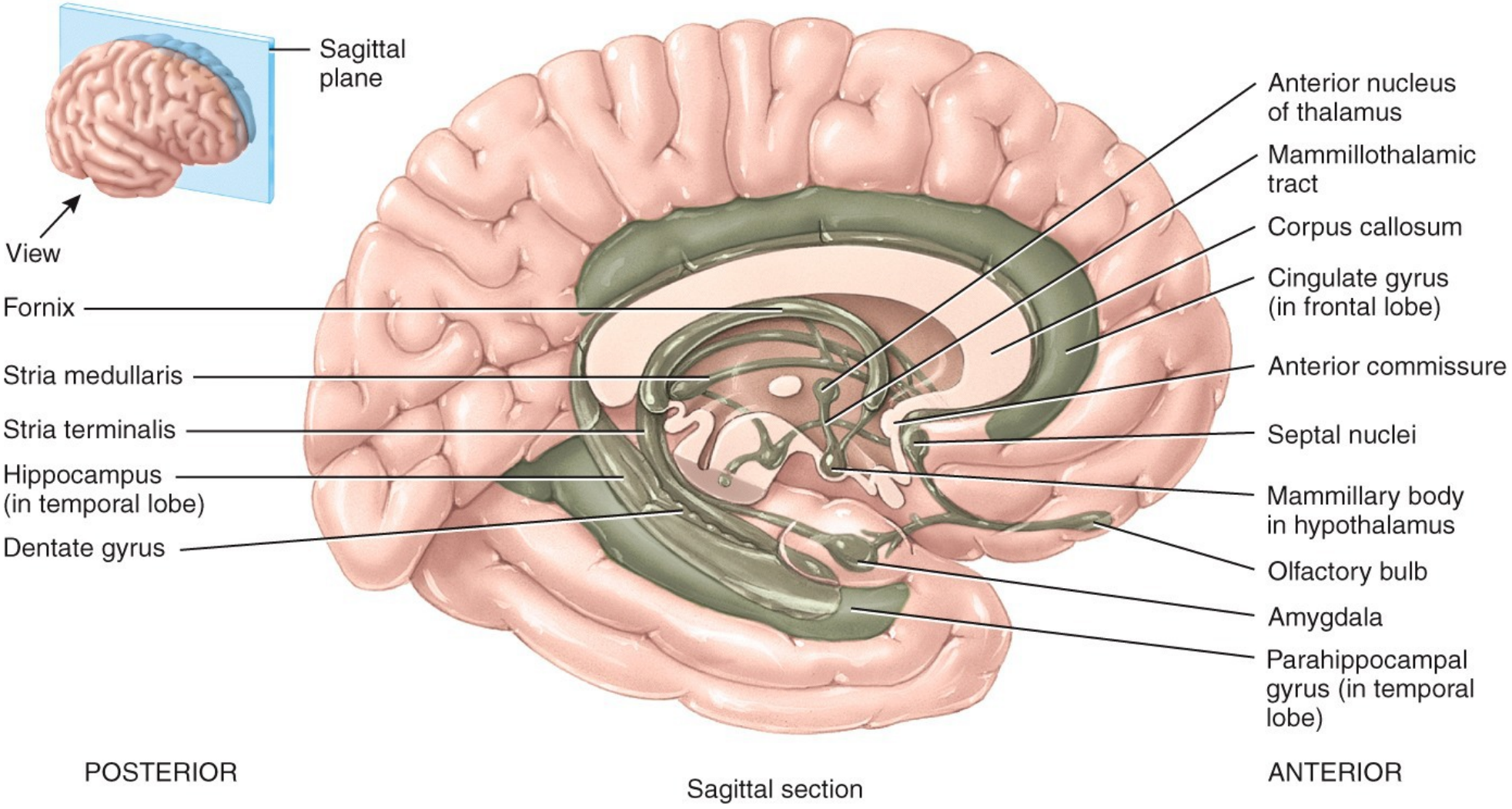
These two systems regulate homeostasis!

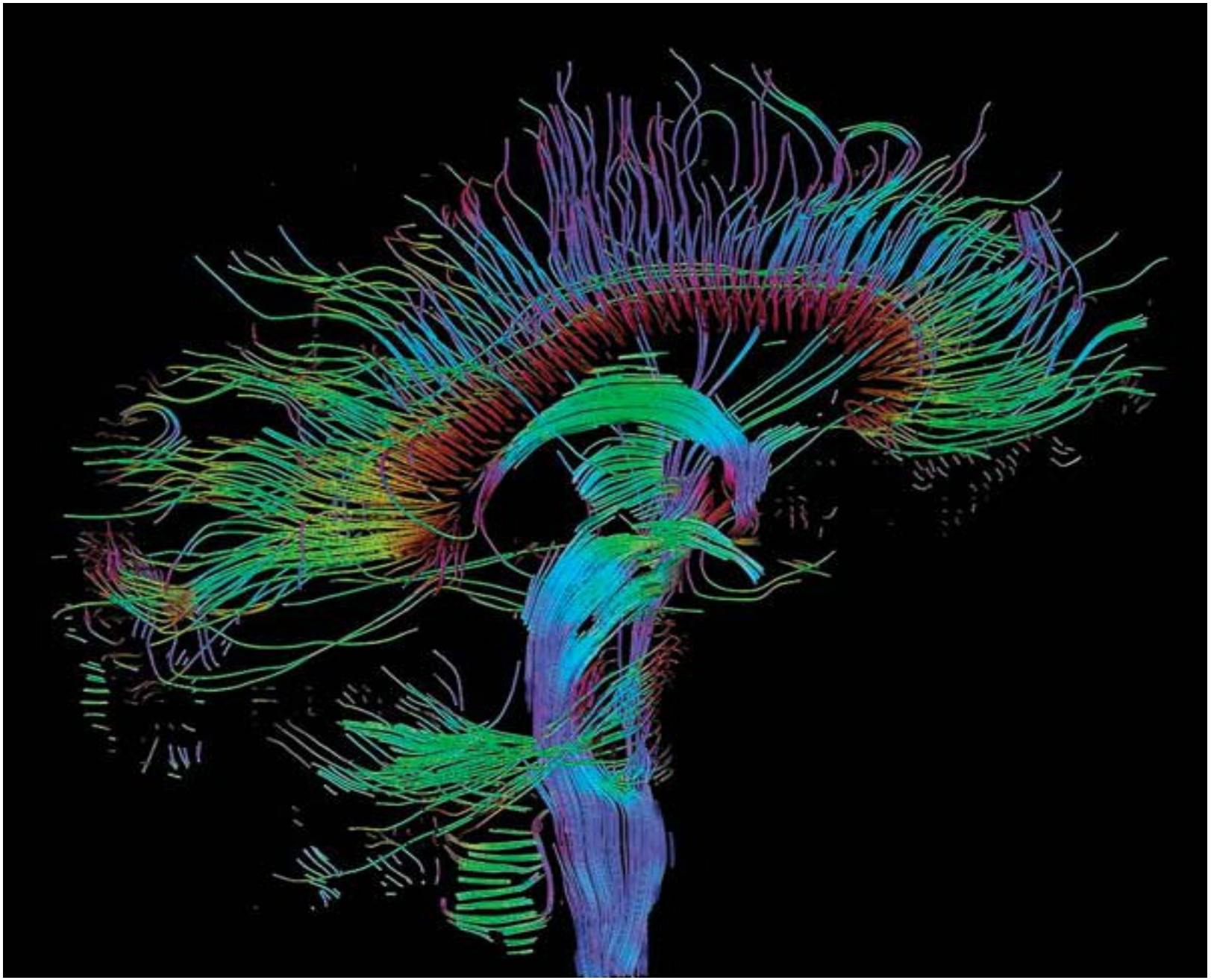


(a) Sagittal section, medial view

The Limbic System

(The Paleo-Mammalian Formation)





The Human Brain

Nerve tracks connect different regions of the brain.

What is stress?

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

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

Stress Produces the General Adaptive Syndrome

- General Adaptation Syndrome (GAS)
  - the consistent way that the 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
  - increasing levels of aldosterone and angiotensin levels released into blood
    - angiotensin helps raise blood pressure
    - aldosterone promotes sodium and water conservation

Stage of Resistance

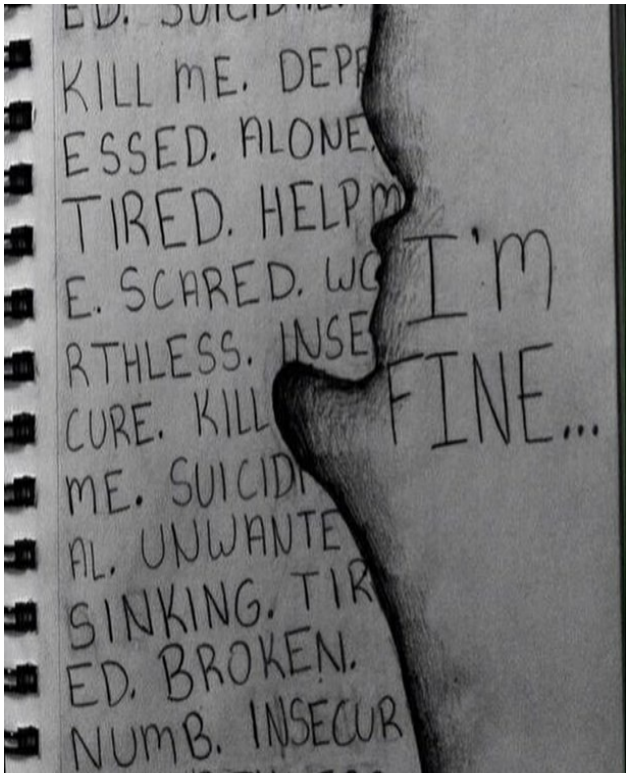
- After a few hours (or days), glycogen reserves are gone (no glucose in storage)
- However, our brain needs glucose /// need to provide alternate sources of glucose for brain metabolism while other non-brain cells use fat catabolism as a source of fuel for their metabolism
- Hypothalamus secretes corticotropin-releasing 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

- Corticsol is responsible for the stage of resistance
- Cortisol has glucose-sparing effect
  - inhibits new protein synthesis // while muscle protein is converted 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
    - re-positions fat deposits in body (from limbs to face & back)
    - Cortisol will reverse capillary imbalance (i.e. swellingJ) seen during inflammation (i.e. cortisol = anti-inflammatory effect)

Stage of Exhaustion

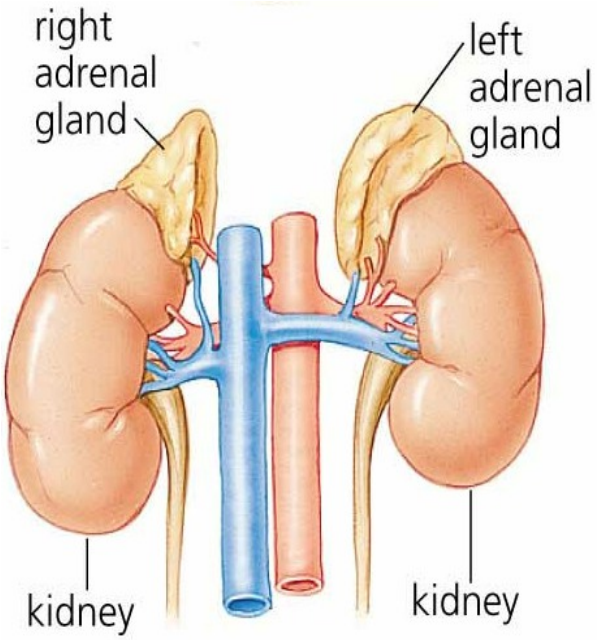
- After stress continues for weeks and/or months
  - fat reserves are gone
  - protein breakdown results in muscle wasting
  - unable to make antibodies = no longer resistant to diseases
  - homeostasis is overwhelmed
  - now physiology enters stage of rapid decline

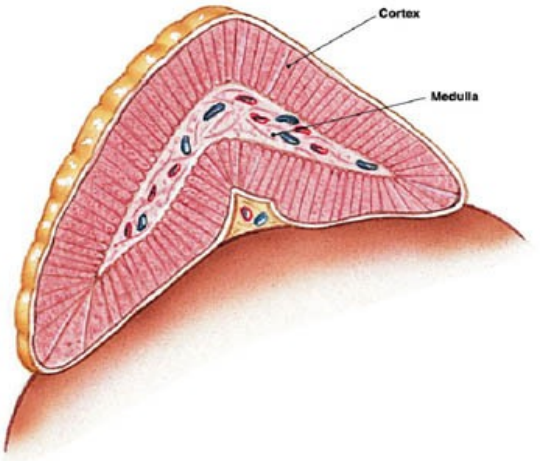


- Furthermore....
  - the loss of glucose homeostasis occurs because adrenal cortex stops producing glucocorticoids
  - however, the adrenal gland continues to produce mineralcorticoids // leads to electrolyte imbalance

Late 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 // immune system shut down





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

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

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

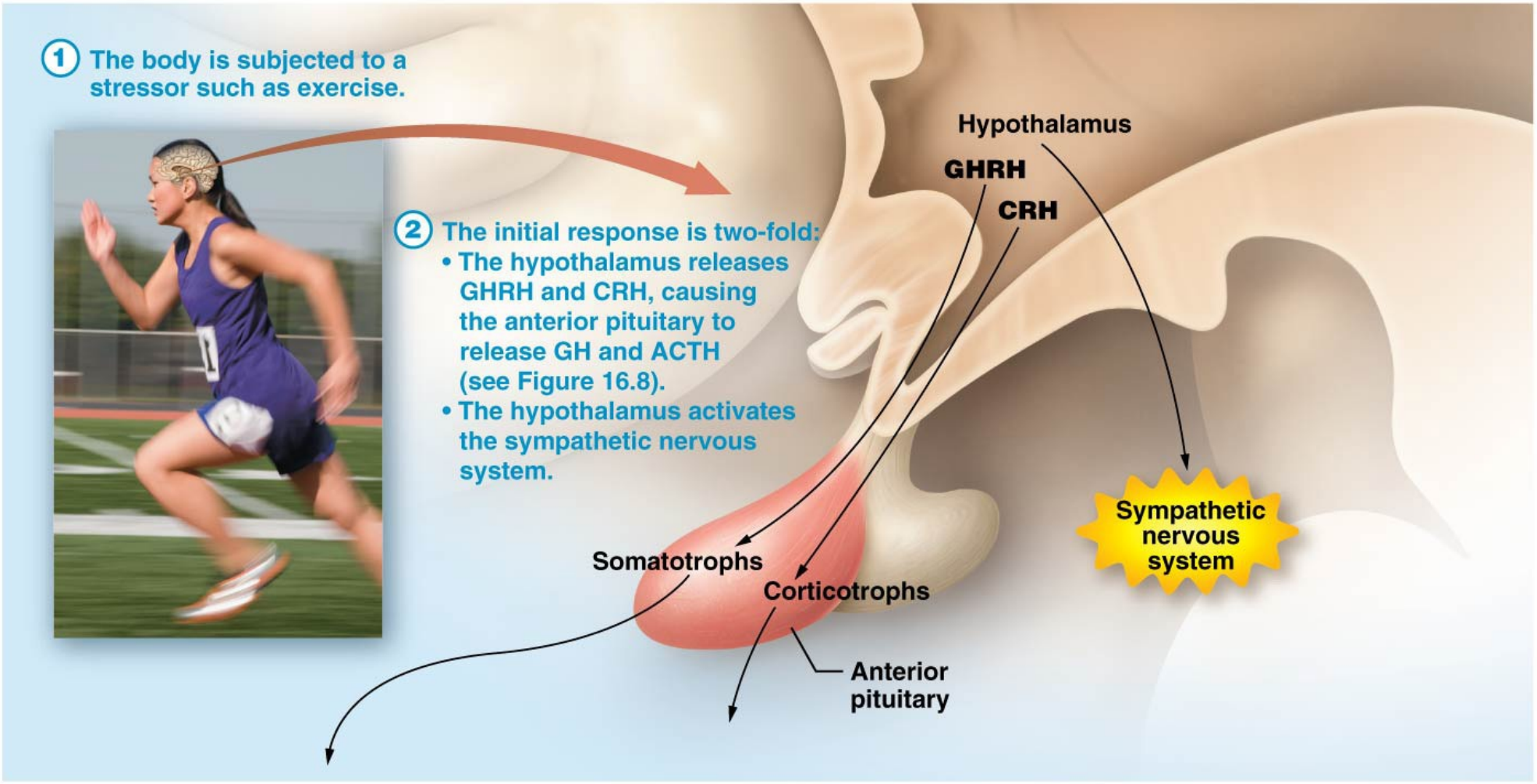
However, if this period of grieving continues for an extended period then this initiates the alarm stage of the GAS

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 step in and break the GAS pathway in order to prevent the grieving spouse from “dying from a broken heart”.

Lee Atwater

The Big Picture of the Hormonal Response to Stress



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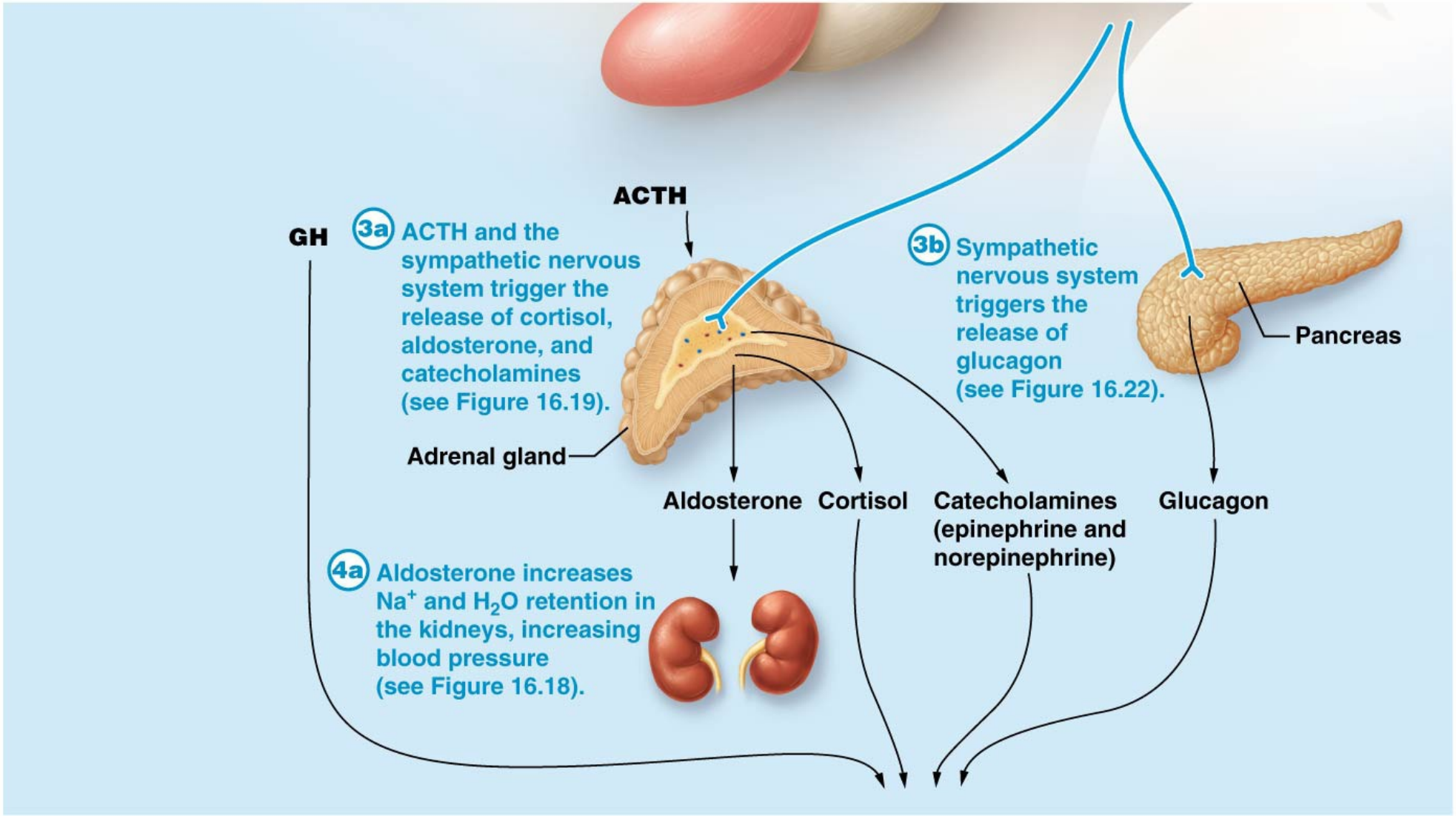
The Big Picture of the Hormonal Response to Stress



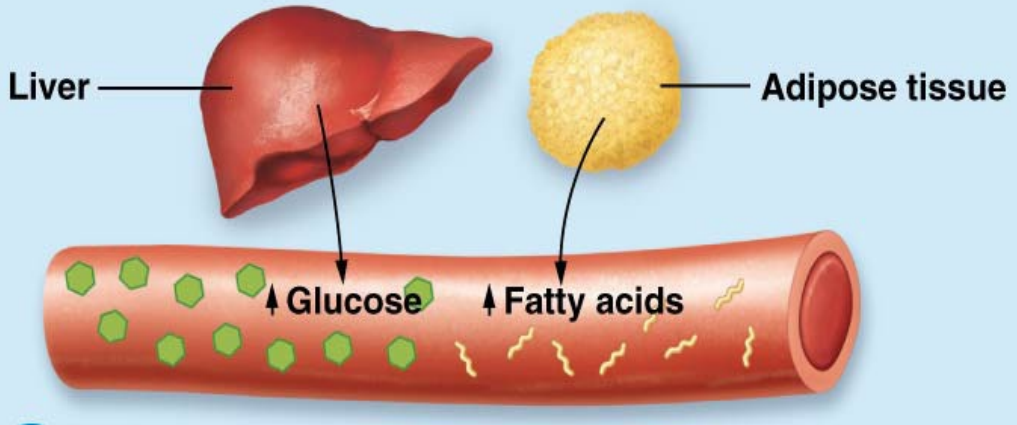
The Big Picture of the Hormonal Response to Stress

GHRH = Growth hormone–releasing hormone

CRH = Corticosteroid-releasing hormone

GH = Growth hormone

ACTH = Adrenocorticotropic hormone



4b GH, cortisol, catecholamines, and glucagon trigger an increased release of metabolic fuels from the liver and adipose tissue.