Physiology

Anatomy, physiology, …

- Anatomy is the science of the structure
- Physiology is the science of the function
- Anatomy and physiology are closely linked, in particular physiology cannot be understood without anatomy
- In many respects, both are ‘closed sciences’

Aim

- The goal of physiology is to explain the physical and chemical factors that are responsible for
- Origin
- Development &
- Progression of life

- Try to explain the specific characteristics and mechanisms of the human body that make it a living being
- Basic unit of human body is the cell
- Each organ is an aggregate of many cells held together by supporting by supporting structures

- Each cell is adapted to performing a particular function(s)
- Eg red cells to carry oxygen, white cells for defense, nerve cells for transmission of impulses

- Though many of the cells differ from one another, have same basic structure
- In all O2 reacts with carbohydrates, fats or lipids for energy
- Same organelles – nucleus, mitochondria etc

Internal enviroment

- 60% body is fluid
- Most inside cells- intracellular fluid – ICF
- 30% in space in between cells – extracellular fluid
- ECF in constant motion throughout the body
- Transported rapidly in blood then mixed between blood and tissue fluids by diffusion through capillary walls

- All cells live within same environment – ECF
- ECF also called internal environment of body
- Cells capable of living, growing and performing their special functions as long as the proper conc’n of O2, glucose, different ions, amino acids, fatty acids, and other constituents are available in this internal environment.

ECF and ICF

- ECF has large amounts of Na, Cl, and bicarbonate ions and glucose, fatty acids and amino acids as well as CO2 from cells under transport from cells to lungs
- ICF has lots of Phosphates, K, and Mg ions,

Homeostasis

- Is maintenance of nearly constant conditions in the internal environment
- Eg lungs provide oxygen to ECF to replenish 02 used by the cells, GIT provides nutrients for use by the cells etc

- Normal healthy living of large organisms including human beings depends upon the constant maintenance of internal environment within the physiological limits.
- If the internal environment deviates beyond the set limits, body suffers from malfunction or dysfunction.
- Therefore, the ultimate goal of an organism is to have a normal healthy living, which is achieved by the maintenance of internal environment within set limits.

- The concept of homeostasis forms basis of physiology because it explains why various physiological functions are to be maintained within a normal range and in case if any function deviates from this range how it is brought back to normal.
- Understanding the concept of homeostasis also forms the basis for clinical diagnostic procedures.
- Eg, Increased body temperature beyond normal range as in the case of fever, indicates that something is wrong in the heat production-heat loss mechanism in the body.
- It induces the clinician to go through the diagnostic proceedings and decide about the treatment

- For the functioning of homeostatic mechanism, the body must recognize the deviation of any physiological activity from the normal limits.
- Fortunately, body is provided with appropriate detectors or sensors, which recognize the deviation.
- These detectors sense the deviation and alert the integrating center.
- The integrating center immediately sends information to the concerned effectors to either accelerate or inhibit the activity so that the normalcy is restored.

- One or more systems are involved in homeostatic mechanism of each function.
- Some of the functions in which the homeostatic mechanism is well established are given below:
- 1. The pH of the ECF has to be maintained at the critical value of 7.4.
- The tissues cannot survive if it is altered. Thus, the decrease in pH (acidosis) or increase in pH (alkalosis) affects the tissues markedly.
- The respiratory system, blood and kidney help in the regulation of pH

- 2. Body temperature must be maintained at 37.5°C. Increase or decrease in temperature alters the metabolic activities of the cells.
- The skin, respiratory system, digestive system, excretory system, skeletal muscles and nervous system are involved in maintaining the temperature within normal limits.
- 3. Adequate amount of nutrients must be supplied to the cells. Nutrients are essential for various activities of the cell and growth of the tissues. These substances also form the source of energy required for various activities of the cells. Nutrients must be digested, absorbed into the blood and supplied to the cells.
- Digestive system and circulatory system play major roles in the supply of nutrients.

- 4. Adequate amount of oxygen should be made available to the cells for the metabolism of the nutrients.
- Simultaneously, the CO2 and other metabolic end products must be removed.
- Respiratory system is concerned with the supply of oxygen and removal of carbon dioxide.
- Kidneys and other excretory organs are involved in the excretion of waste products.

5. Many hormones are essential for the metabolism of nutrients and other substances necessary for the cells.

- Hormones are to be synthesized and released from the endocrine glands in appropriate quantities and these hormones must act on the body cells appropriately.
- Otherwise, it leads to abnormal signs and symptoms.

6. Water and electrolyte balance should be maintained optimally. Otherwise it leads to dehydration or water toxicity and alteration in the osmolality of the body fluids.

- Kidneys, skin, salivary glands and gastrointestinal tract take care of this.

7. For all these functions, the blood, which forms the major part of internal environment, must be normal.

- It should contain required number of normal red blood cells and adequate amount of plasma with normal composition.
- Only then, it can transport the nutritive substances, respiratory gases, metabolic and other waste products.

8. Skeletal muscles are also involved in homeostasis. This system helps the organism to move around in search of food.

- It also helps to protect the organism from adverse surroundings, thus preventing damage or destruction

9. Central nervous system, which includes brain and spinal cord also, plays an important role in homeostasis.

- Sensory system detects the state of the body or surroundings.
- Brain integrates and interprets the pros and cons of these information and commands the body to act accordingly through motor system so that, the body can avoid the damage.

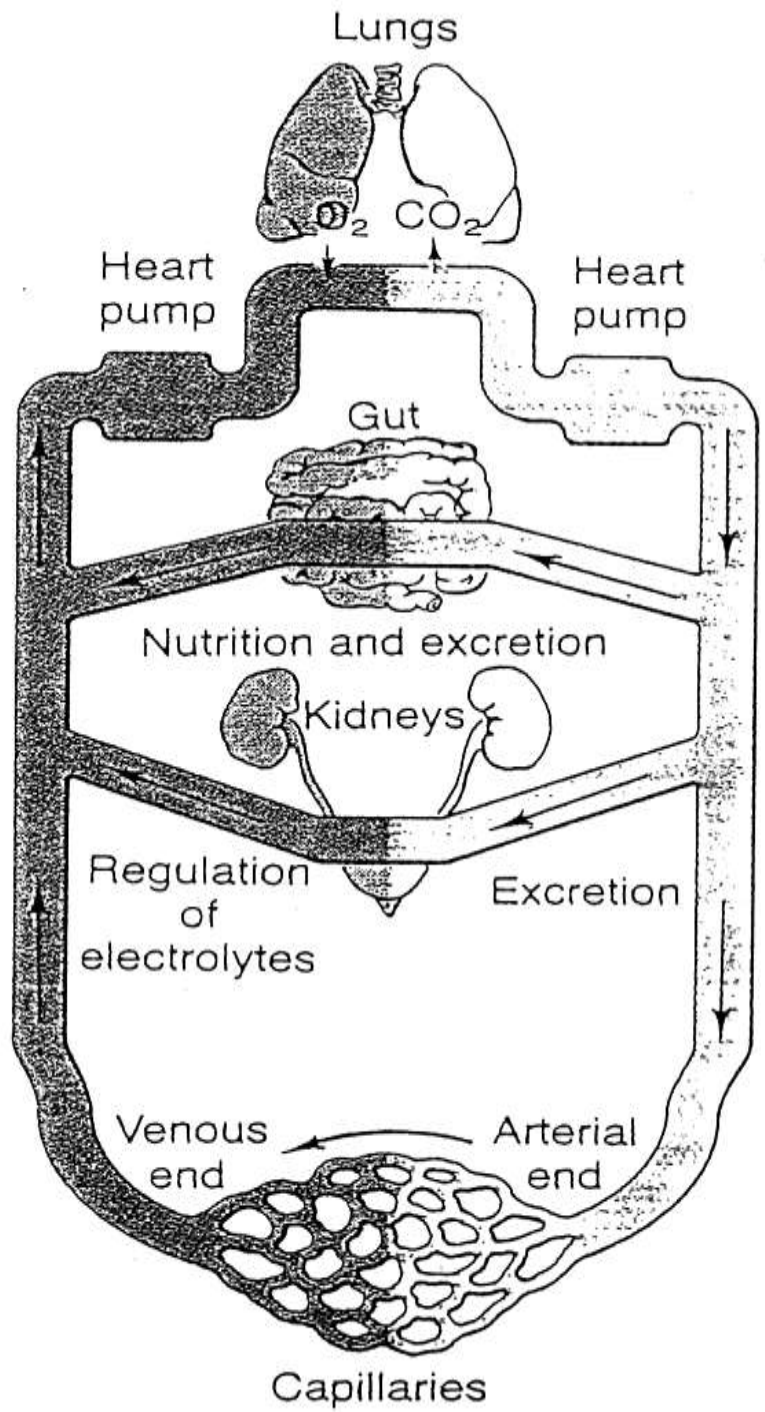
Homeostasis

- The ability of the body to maintain relatively stable internal conditions even though there is continuous change in the outside world
- A state of dynamic equilibrium
- The body functions within relatively narrow limits
- All body systems contribute to its maintenance

Homeostasis

- Some important moments:
- 17th century: William Harvey first describes the closed circulation
- 19th century: Claude Bernard formulates the modern version of homeostasis – the constancy of the internal milieu

- ECF transported throughout body in two stages-
- Through blood in blood vessels
- From capillaries through intracellular spaces and into the cells


Lungs
O_2
CO_2
Heart pump
Heart pump
Gut
Nutrition and excretion
Kidneys
Regulation of electrolytes
Excretion
Venous end
Arterial end
Capillaries

- All blood traverses entire circulatory circuits around once every minute when body is at rest and up to about 6 times when body very active
- As blood passes through the capillaries, continual exchange of ECF occurs also occurs between the plasma portion of blood and the interstitial fluid that fills intercellular spaces

- Capillary walls are permeable to most molecules except large proteins
- Large amounts o f fluids and dissolved molecules diffuse back and forth between blood and tissue spaces by kinetic motion
- Few cells locate over 50 micrometers from capillaries

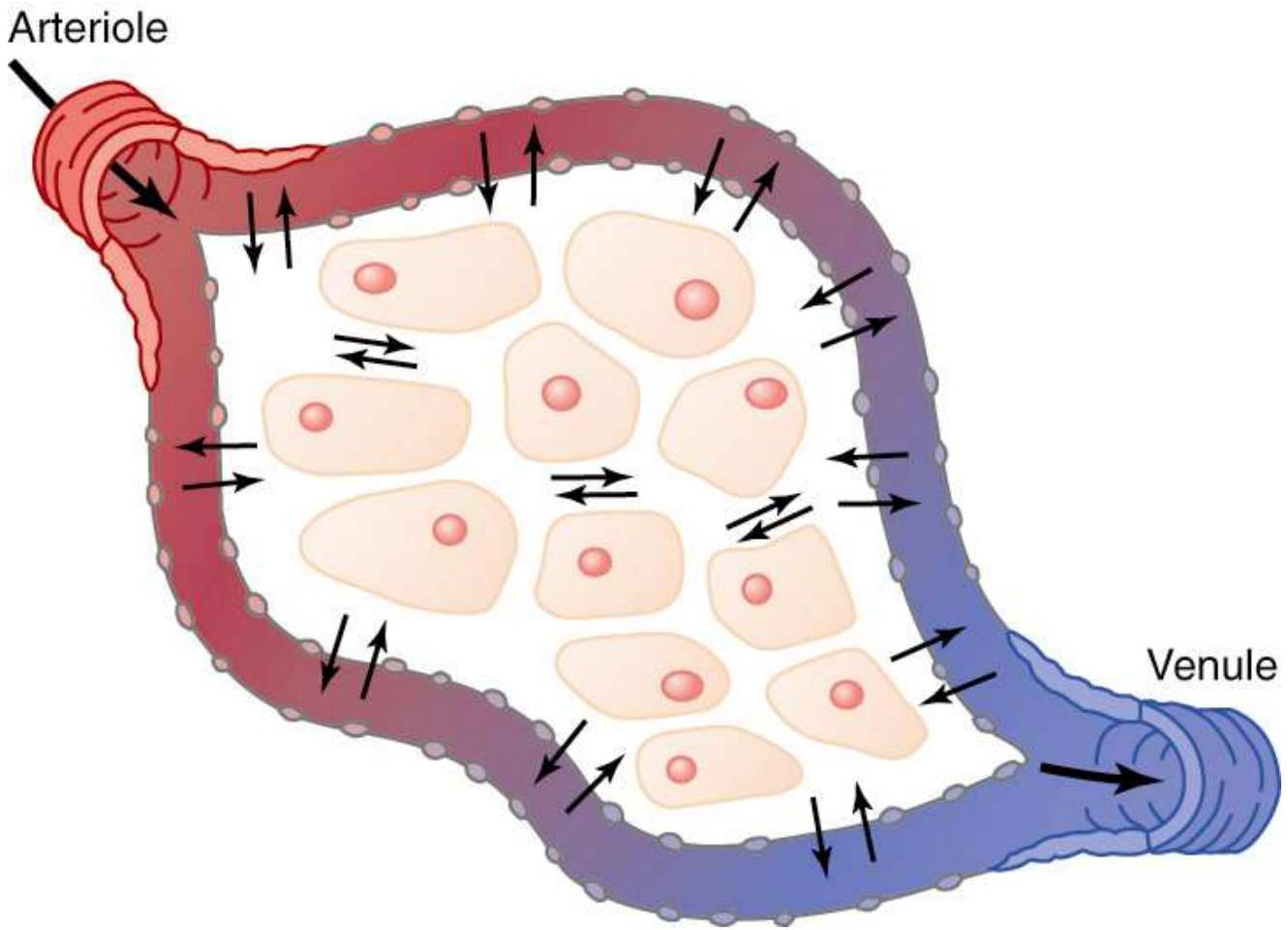


Figure 1-2; Guyton & Hall

- Thus ECF all over body is continually mixed therefore maintaining almost continuous homogenity of ECF throughout the body

Origin of Nutrients in ECF

Lungs

- Every time blood passes through the lungs, it picks up O2 required by cells

GIT

- Most of the blood pumped by heart also passes through the GIT
- From here, it picks up nutrients including carbohydrates, fatty acids and amino acids from ingested food

Liver and other organs

- Not all absorbed substances from GIT can be used in absorbed form by the cells.
- The liver changes chemical composition of this substances to more usable forms
- Other tissues of the body-fat cells, GIT mucosa, kidneys and endocrine glands help modify the absorbed substances or store them till they are required

Musculoskeletal

- Allows the body to move to appropriate place at the appropriate time to obtain food for nutrition
- Also protects mechanism for digestion of ingested food
- Protection against adverse surroundings

Removal of metabolic end products

Carbon dioxide by lungs

As blood picks O_2 from lungs, it also delivers CO_2 to the lungs from the tissues for expiration

Kidneys

- As blood passes through kidneys, most of the substances nor required by body apart from CO2 removed
- Includes end products of cellular processes such as urea, uric acid, excess ions and water

Regulation of body functions

Nervous system

- Sensory input
- Central nervous system (integrative portion)
- Motor output portion
- Sensory detects state of body or surrounding eg sensory receptors on skin detect when an object touching the skin or eyes see the surrounding or ears hear something

- Integrative part consists of brain and spinal cord
- Brain can store information, generate thoughts, and determine reactions that the body performs in response to sensation
- Appropriate signals are then sent to the motor output of the nervous system

- Large segment of nervous system is the Autonomic nervous system which operates at subconscious level and controls many functions of the internal organs such as the heart, GIT movements and secretions by many glands

Hormonal system

- Body has 8 major secretory glands
- Produces hormones which are transported thru' ECF to all parts of body to help regulate cell function
- Eg: thyroid hormone increases rates of all chemical reactions in body.
- Insulin controls glucose metabolism

Reproduction

- Sometimes not considered homeostatic function
- However helps by generation new beings to replace those that are dying

- This may sound like a permissive usage of the term *homeostasis,* but it illustrates that, in the final analysis, essentially all body structures are organized such that they help maintain the automaticity and continuity of life.

Control Mechanisms

- Regardless of the factor or event (variable) being regulated, all homeostatic control mechanisms have at least three interdependent components
  - Receptor (stimuli of change is detected)
  - Control center (determines response)
  - Effector (bodily response to the stimulus)

- Homeostatic mechanisms are designed to reestablish homeostasis when there is an imbalance.
- An example of such is a home heating system

The Home Heating System

- When the temperature of a room decreases below a set point, the thermostat electrically starts the furnace.
- As the temperature of the room rises to the set point, the thermostat shuts down the furnace.
- As the room cools, step one is repeated.
- There are three components to this system:
- The Sensor which detects the stress.
- The Control Center which receives information from the sensor and sends a message to the Effector.
- The Effector which receives the message from the control center and produces the response which reestablishes homeostasis.

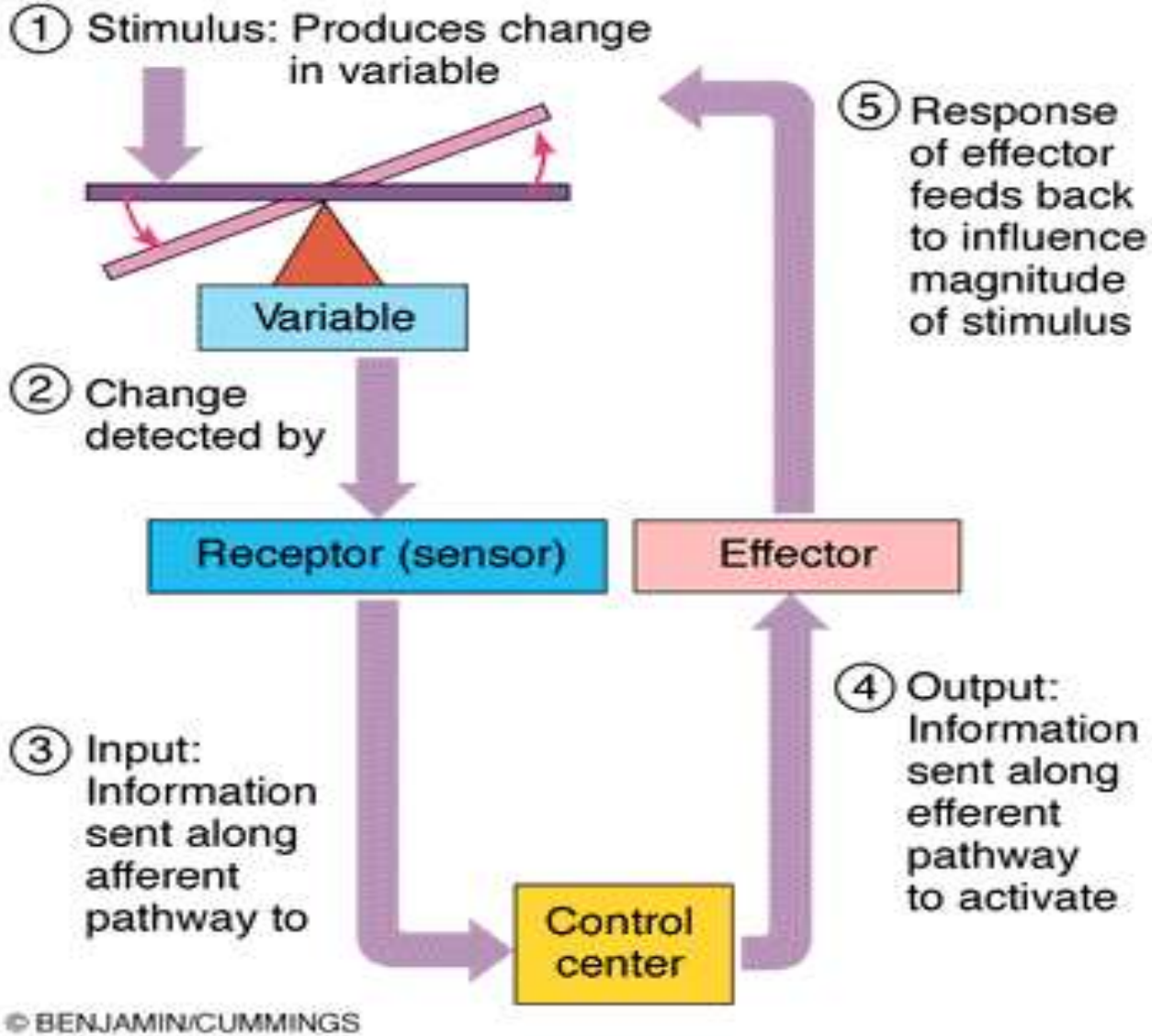
- There are three components to a homeostatic system:

1. The Sensor which detects the stress.

2. The Control Center which receives information from the sensor and sends a message to adjust the stress.

3. The Effector which receives the message from the control center and produces the response which reestablishes homeostasis

- It should be noticed that
  1. the heat produced by the furnace shuts the furnace down through the thermostat.
  2. the original stress is reduced, i.e., the room warms up.
- **Homeostatic mechanisms that show these two characteristics are operating by negative feedback**


1 Stimulus: Produces change in variable
Variable
2 Change detected by
Receptor (sensor)
3 Input: Information sent along afferent pathway to
Control center
4 Output: Information sent along efferent pathway to activate
Effector
5 Response of effector feeds back to influence magnitude of stimulus
© BENJAMIN/CUMMINGS

Control Mechanisms

- A chain of events . . .
- Stimulus produces a change in a variable
- Change is detected by a sensory receptor
- Sensory input information is sent along an afferent pathway to control center
- Control center determines the response
- Output information sent along efferent pathway to activate response
- Monitoring of feedback to determine if additional response is required

Negative feedback mechanism

- Most control mechanisms are negative feedback mechanisms
- A negative feedback mechanism decreases the intensity of the stimulus or eliminates it
- The negative feedback mechanism causes the system to change in the opposite direction from the stimulus
- Example: home heating thermostat

Positive feedback mechanism- 5th Sept

- A positive feedback mechanism enhances or exaggerates the original stimulus so that activity is accelerated
- It is considered positive because it results in change occurring in the same direction as the original stimulus
- Positive feedback mechanisms usually control infrequent events such as blood clotting or childbirth

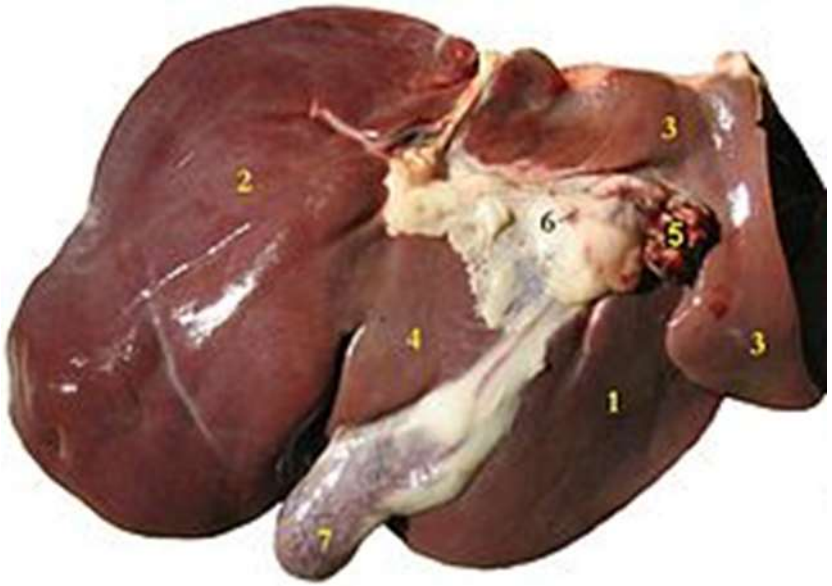
- Thus, if some factor becomes excessive or deficient, a control system initiates *negative feedback,* which consists of a series of changes that return the factor toward a certain mean value, thus maintaining homeostasis.

Regulation of Blood Glucose Concentration

- Blood sugar level must be kept within a certain range to provide the energy needed by cells for:
- Synthesis of DNA, proteins and other complex molecules.
- Active uptake of ions.
- Muscle contraction.
- Cells are therefore constantly using up the blood sugar.
- To ensure a regular supply regardless of food consumed the body uses homeostasis!

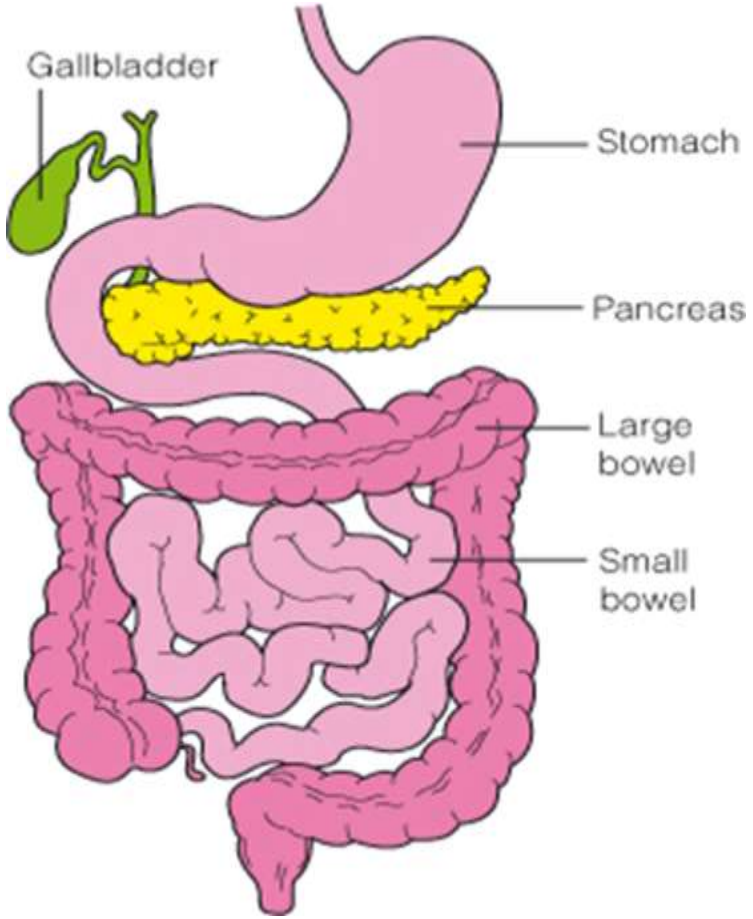
Liver as a storehouse

- About 100g of glucose is stored as GLYCOGEN in the liver.
- Glucose can be added or removed from this reservoir of stored carbohydrate depending on supply and demand.



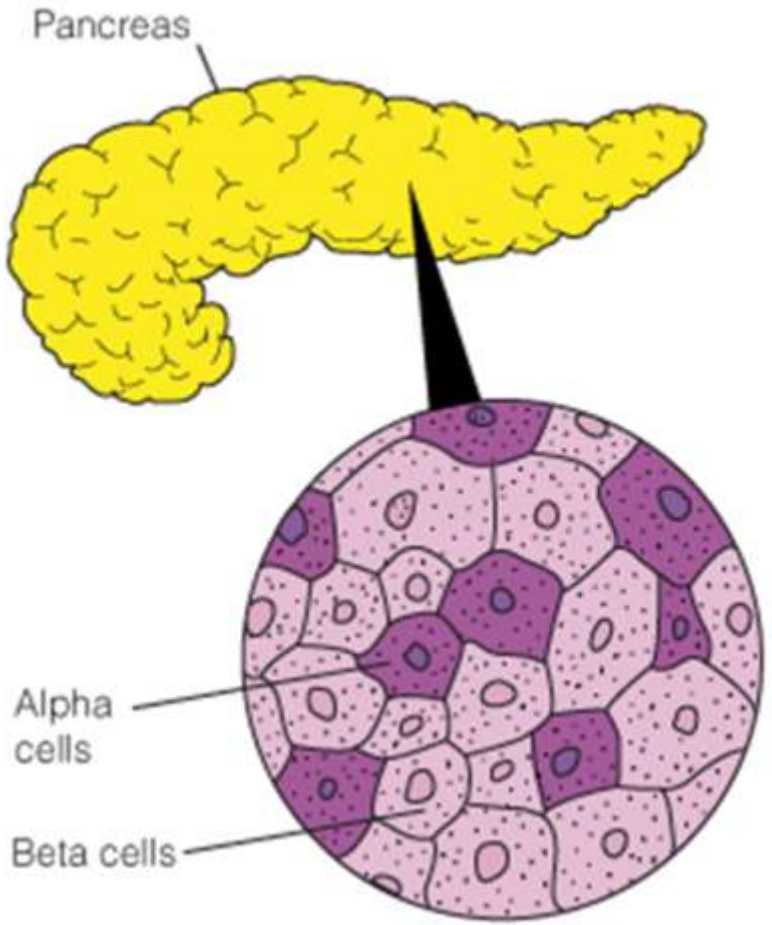
Control of blood sugar: Insulin and glucagon

- nsulin and glucagon are two hormones that control how much glucose (sugar) is in the blood
- These hormones are made in the pancreas.
- Your pancreas contains small groups of cells called the islets (or islands) of Langerhans.



Pancreas

- When you eat a meal, the amount of sugar in your blood rises. The cells in your pancreas react by making more insulin.
- When your blood sugar levels are low, the cells in your pancreas react by making more glucagon.



What does insulin do?

- After digestion, glucose enters your bloodstream.
- The Islets of Langerhans in the pancreas detects an increase in blood sugar level.
- These cells produce the hormone insulin, which is then transported to the liver in the bloodstream.
- Insulin activates an enzyme to catalyze the reaction

glucose ——— glycogen

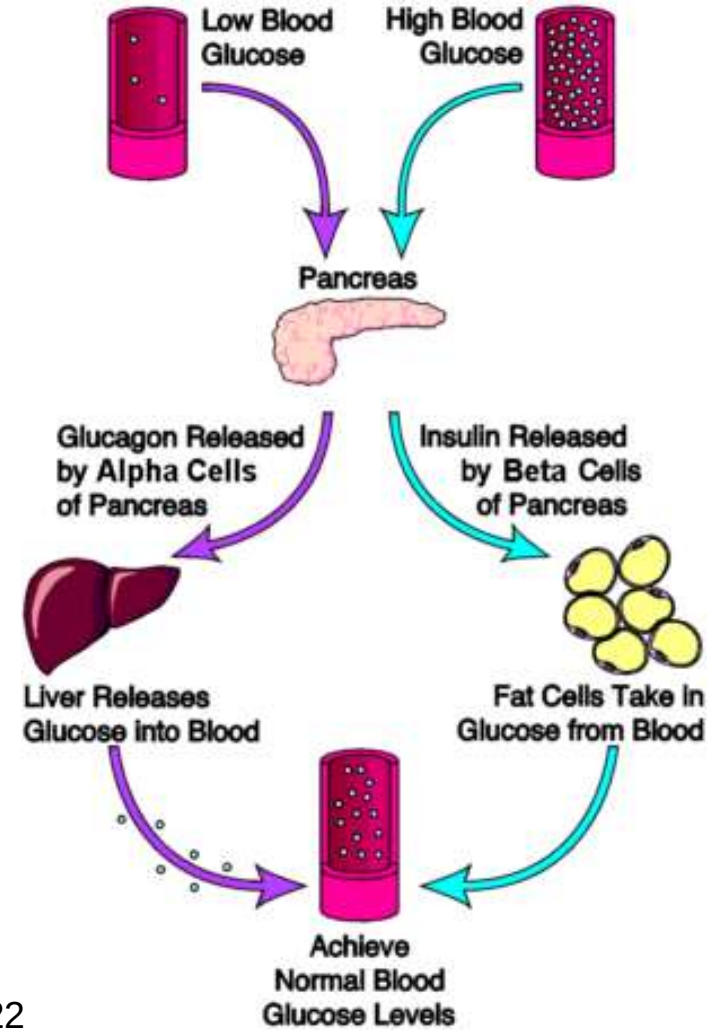
- This decreases the blood sugar level.
- Glycogen, a long chain carbohydrate, is stored in the liver until it is needed e.g. when you are sleeping

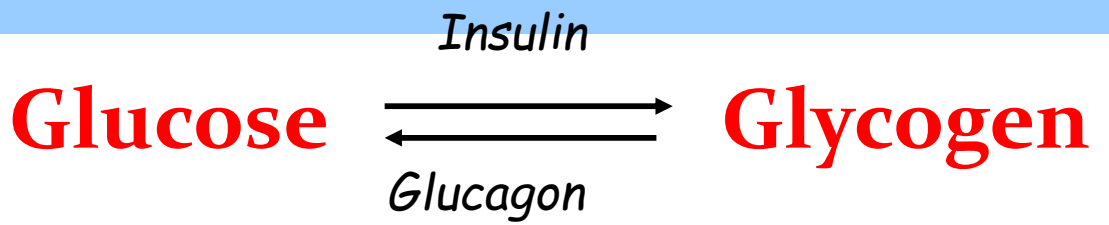
What does glucagon do?

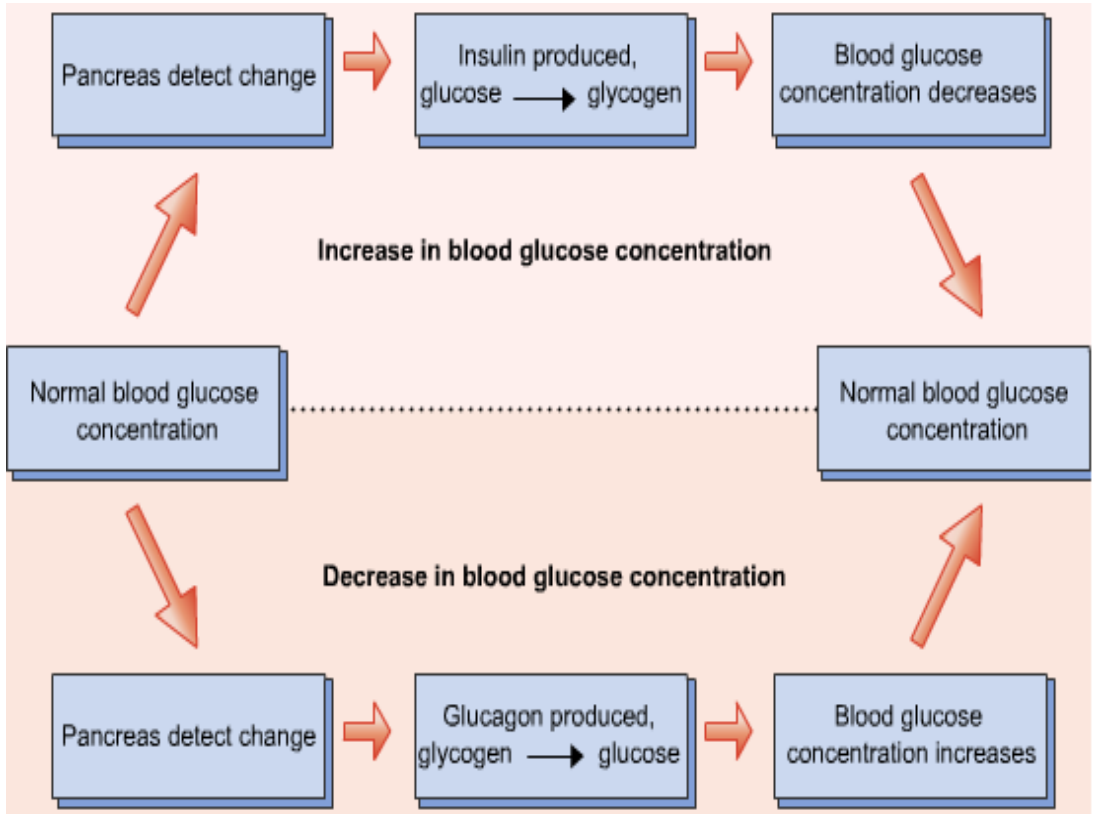
- **Glucagon stops your blood glucose level from dropping too low.**
- When you exercise, your body uses the glucose in your blood to power your muscles. Your pancreas senses that you're using up your glucose supply.
- As your blood glucose level drops, your pancreas stops making insulin and your pancreas makes glucagon
- Glucagon activates an enzyme in your liver which catalyzes the following reaction

- These activities push up the amount of glucose in your blood.

Control of blood sugar

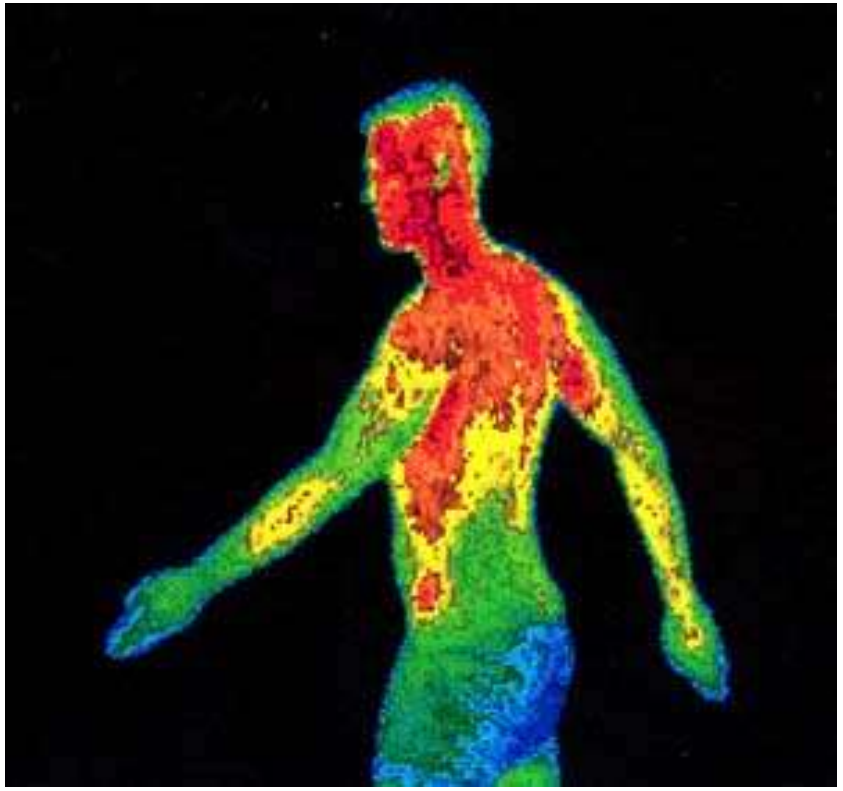






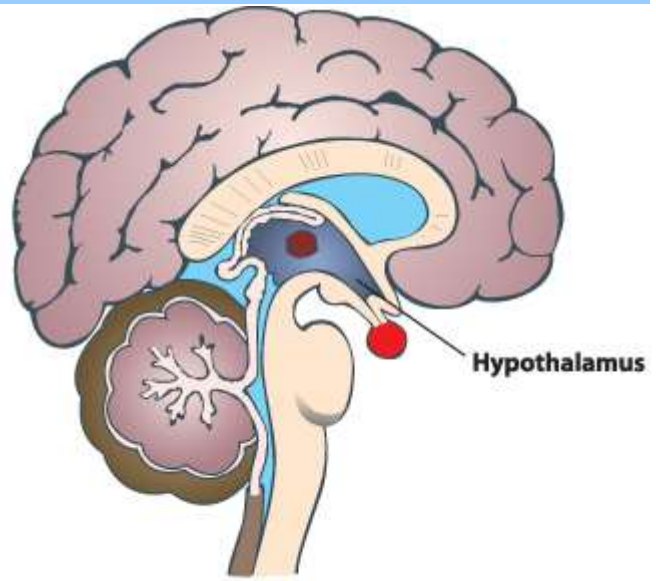
Control of body temperature

- Core body temperature must remain at 37^{o}C
- Careful control of the blood supply to the skin can do this by reducing blood flow to the colder extremities in cool conditions.



Regulation of Body Temperatur

- Another example of homeostasis is the body's regulation of body temperature.



- The hypothalamus (the body's temp-monitoring centre)monitors body temperature in two ways:
  1. It contains central thermoreceptors which are sensitive to temperature changes in the blood, allowing detection of the body's core temperature.
  2. It acts as a thermostat by detecting nerve impulses from thermoreceptors in the skin (this conveys info about the surface temp of the body).

Regulation of Body Temperature

The hypothalamus sends nerve impulses to the effectors allowing the body to correct overcooling or overheating by:

1. Production of sweat.
2. Control of body hairs.
3. Vasodilation or Vasoconstriction of blood flow in the skin

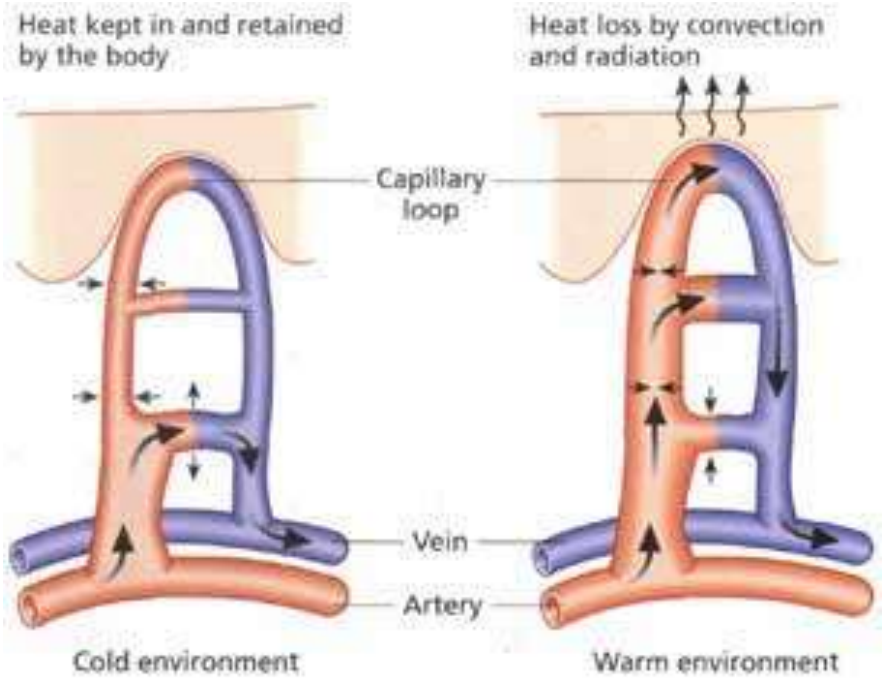
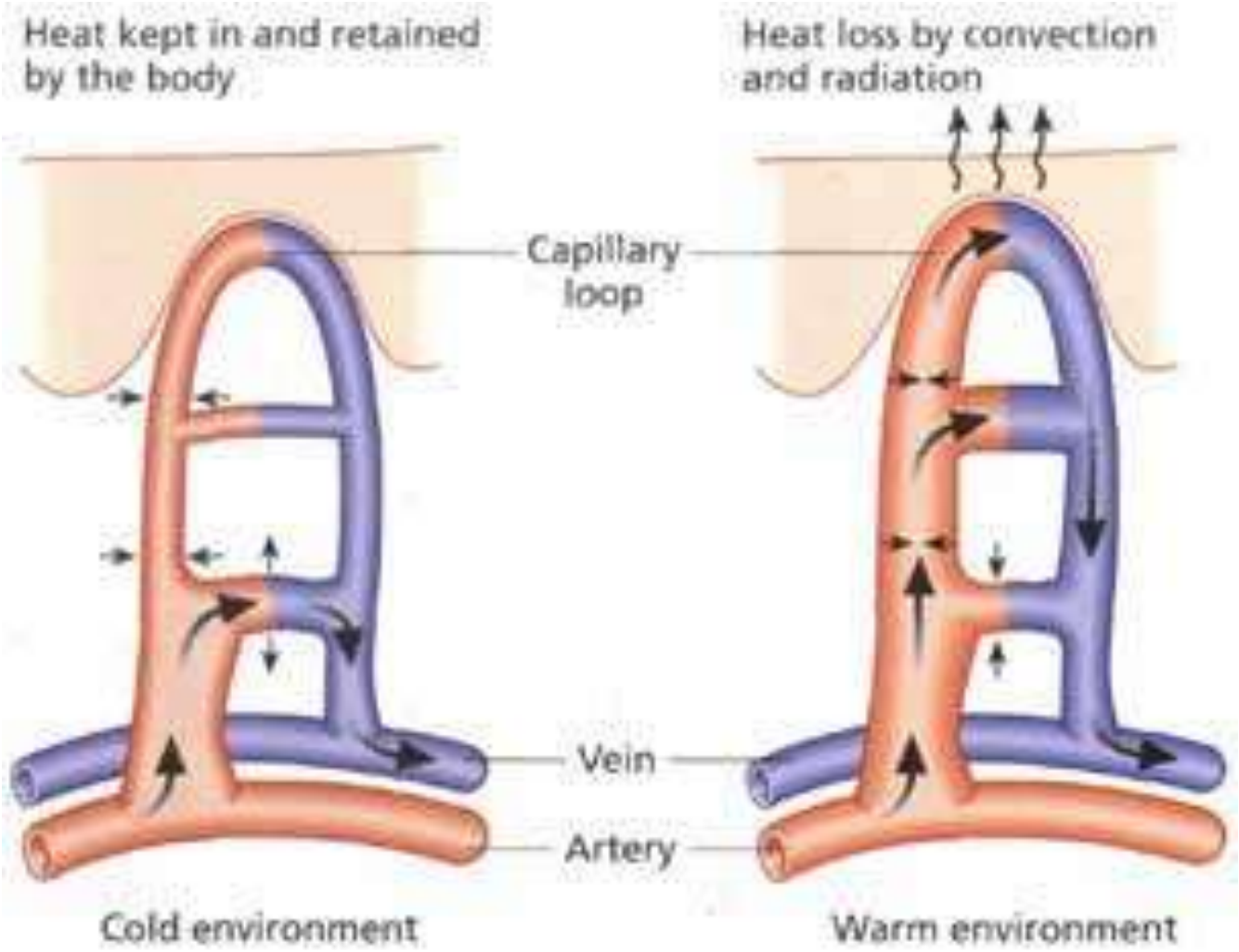
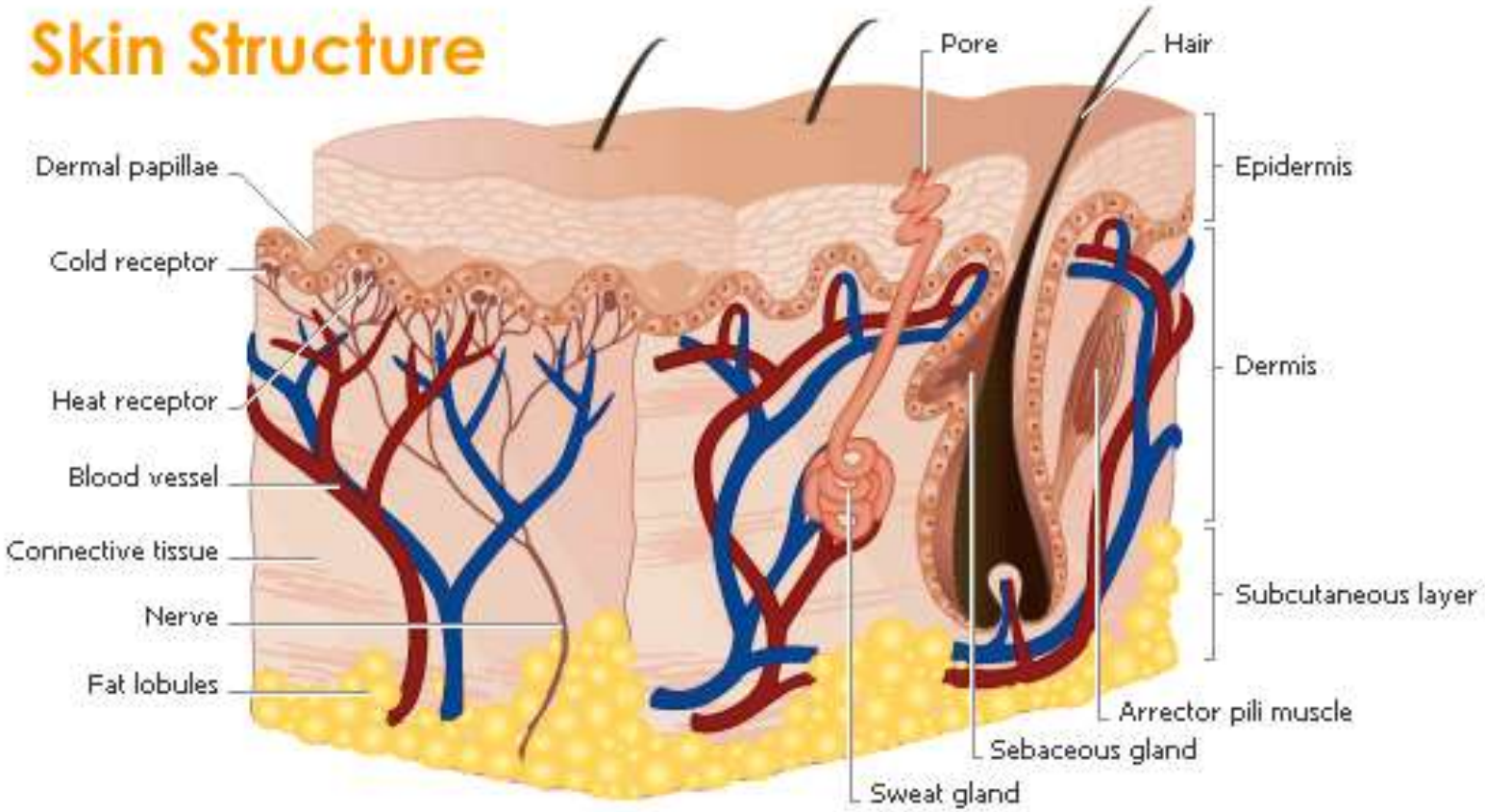


Image source: www.pg.com


Heat kept in and retained by the body
Heat loss by convection and radiation
Capillary loop
Vein
Artery
Cold environment
Warm environment

Role of the Skin

The skin plays a leading role in temperature regulation. In response to nerve impulses from the hypothalamus the skin can act as both a **receptor** and an **effector.**



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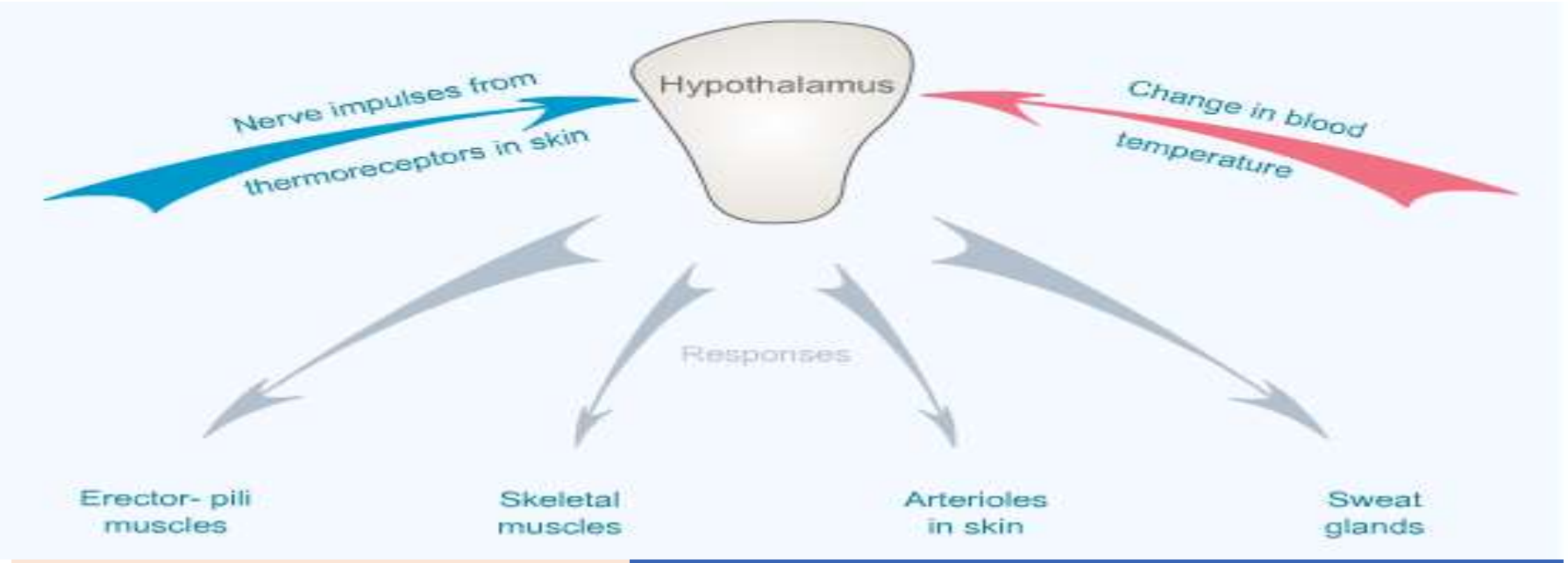
Role of the Skin



The skin helps to correct overheating of the body by

Increasing the rate of sweating.

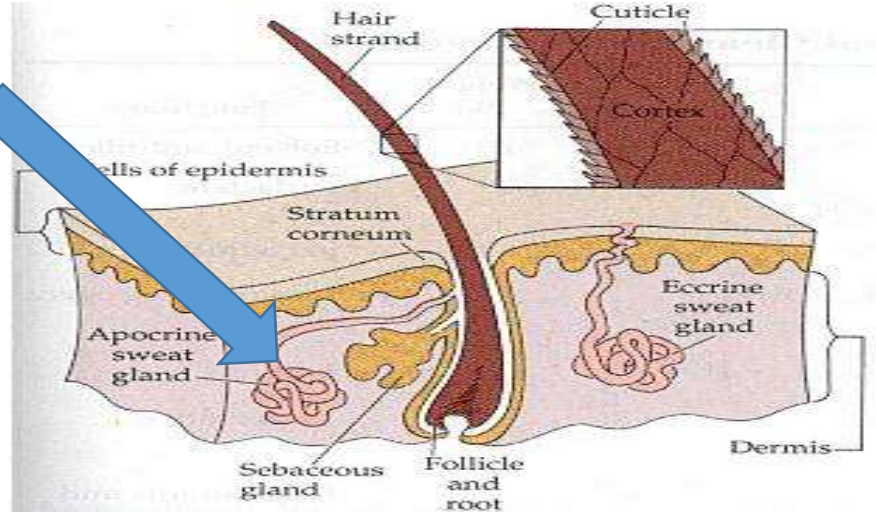
Vasodilation

The skin help to correct overcooling of the body by

3. Decreasing the sweat of sweating.
4. Vasoconstriction
5. Contraction of erector muscles

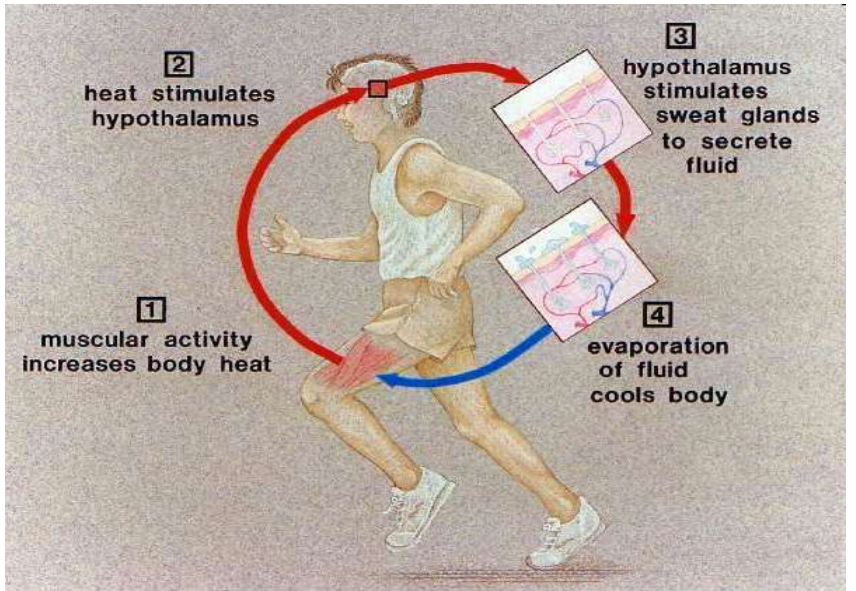
Correcting and heat loss and gain . Sweating - Why sweat?

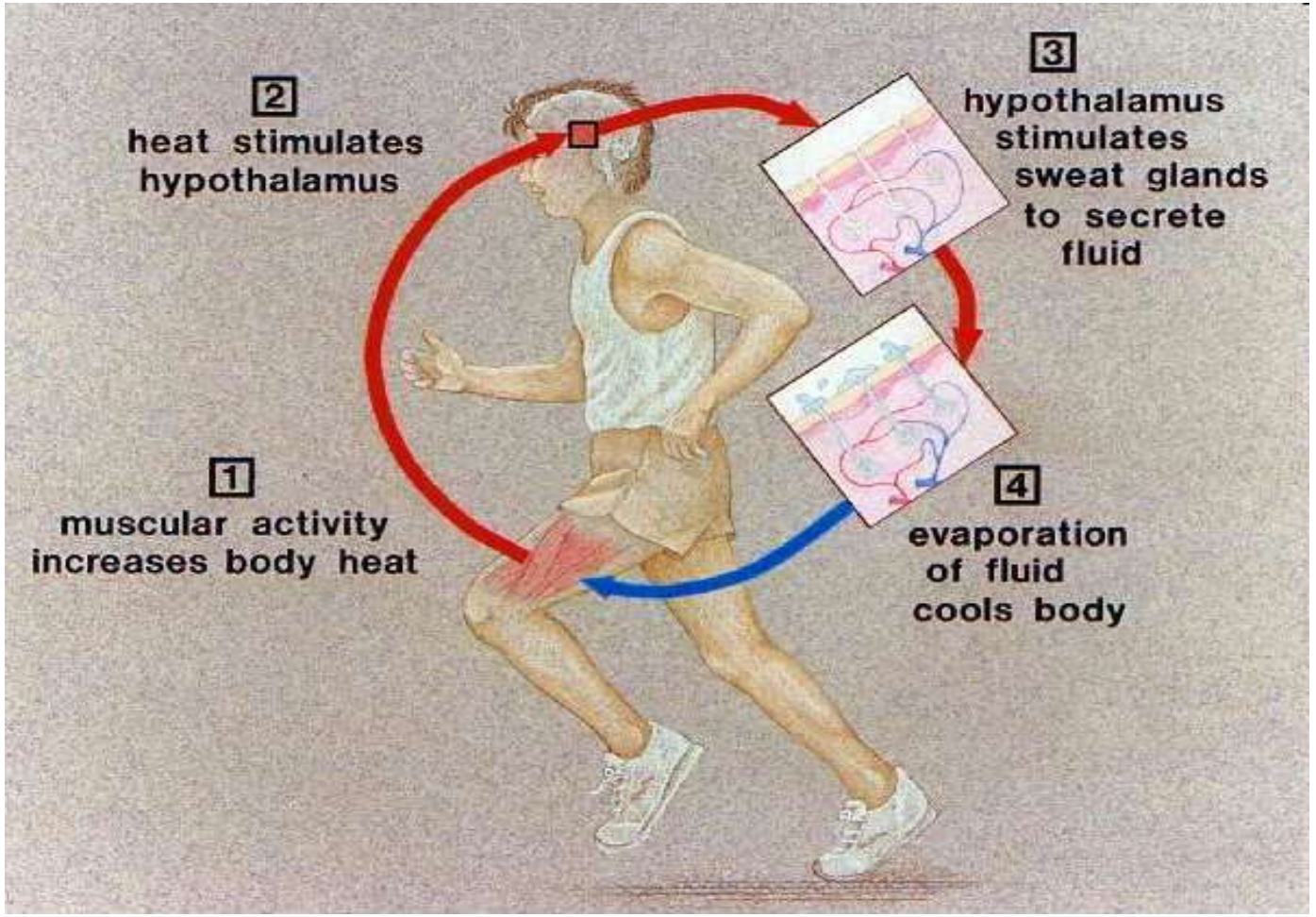
Sweat glands dampen the skin. This loses heat by causing evaporation of the sweat

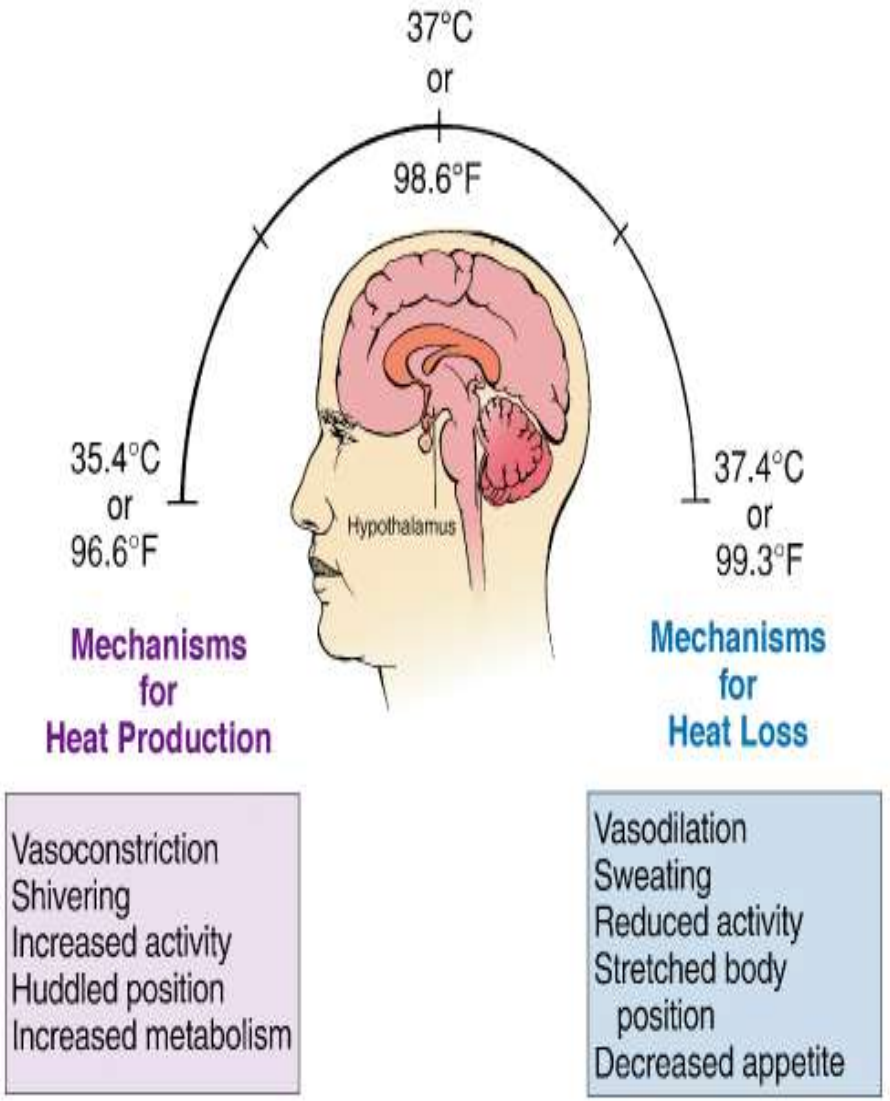


1. When we sweat, heat energy from the body causes water from sweat to evaporate which cools the body.

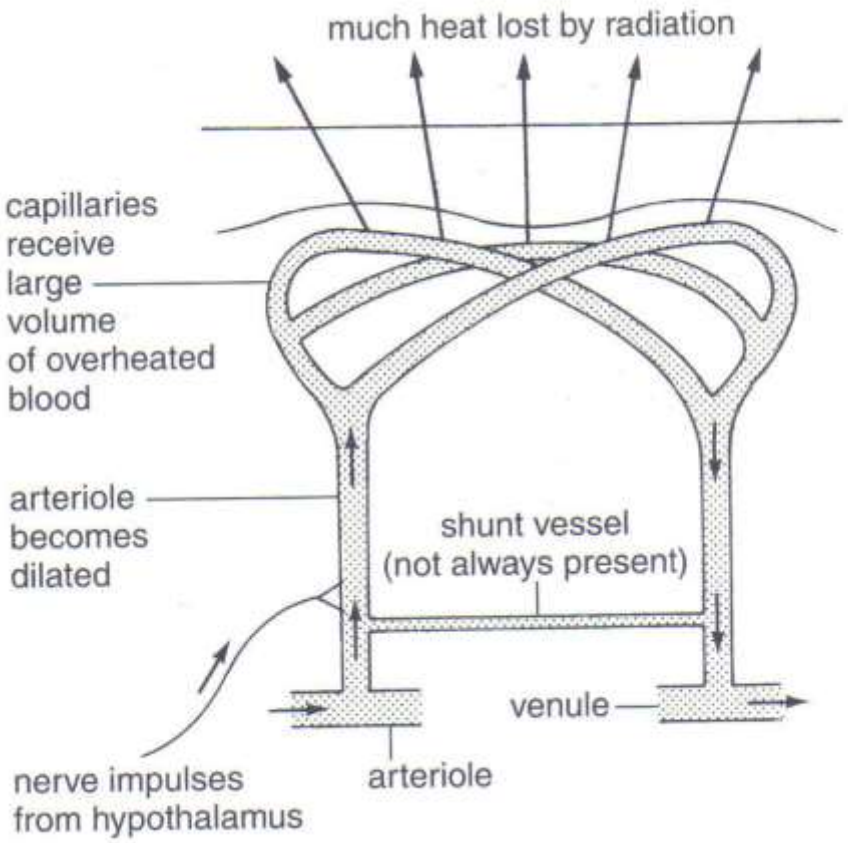
3. When we are cold sweating in inhibited to conserve heat.




2
heat stimulates hypothalamus
3
hypothalamus stimulates sweat glands to secrete fluid
1
muscular activity increases body heat
4
evaporation of fluid cools body


37°C
or
98.6°F
35.4°C
or
96.6°F
37.4°C
or
99.3°F
Hypothalamus
Mechanisms for Heat Production
Vasoconstriction
Shivering
Increased activity
Huddled position
Increased metabolism
Mechanisms for Heat Loss
Vasodilation
Sweating
Reduced activity
Stretched body position
Decreased appetite

2. Correct overheating: Vasodilatation

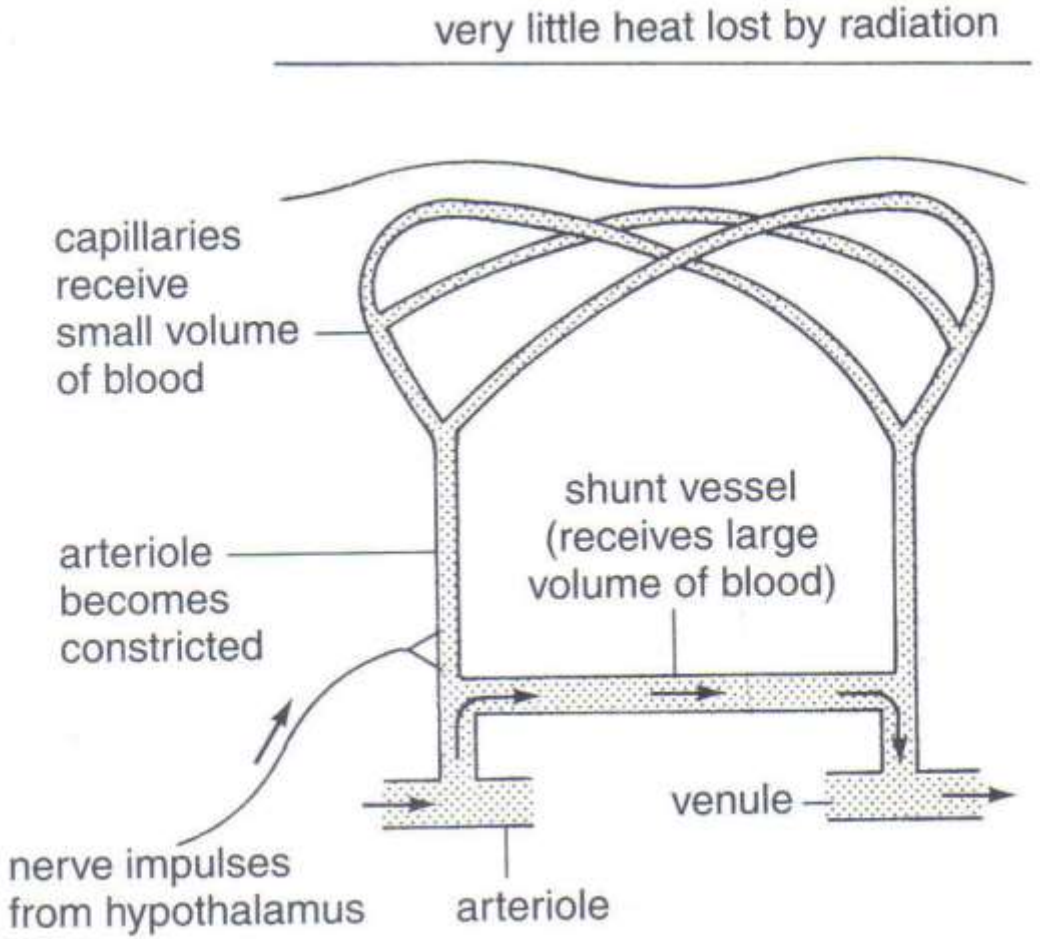


When we get **too hot** arterioles leading to the skin become **dilated**, which allows lots of blood to flow near the skins surface and a loss of heat from the blood by radiation.

FYI: Red skin indicates vasodilatation, Alcohol increases this hence rosy cheeks after a few tipples!

4. Correct overcooling: Vasoconstriction

When we are **cold** arterioles leading to the skin become **constricted**, which reduces the flow of blood to the skins surface so only a little heat is lost from the blood by radiation.

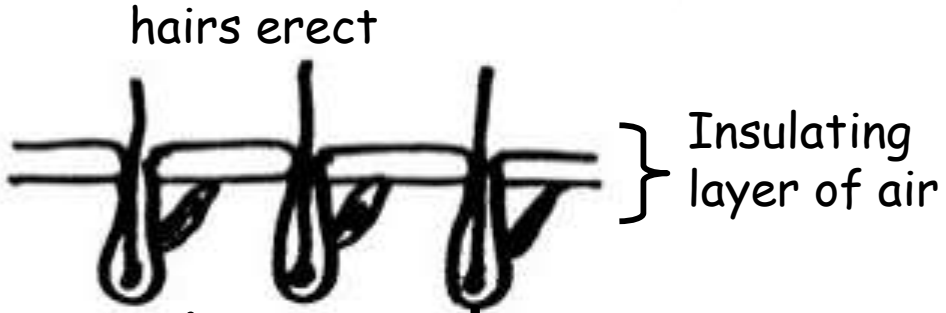


5: Preventing overcooling: Contraction of erector muscles

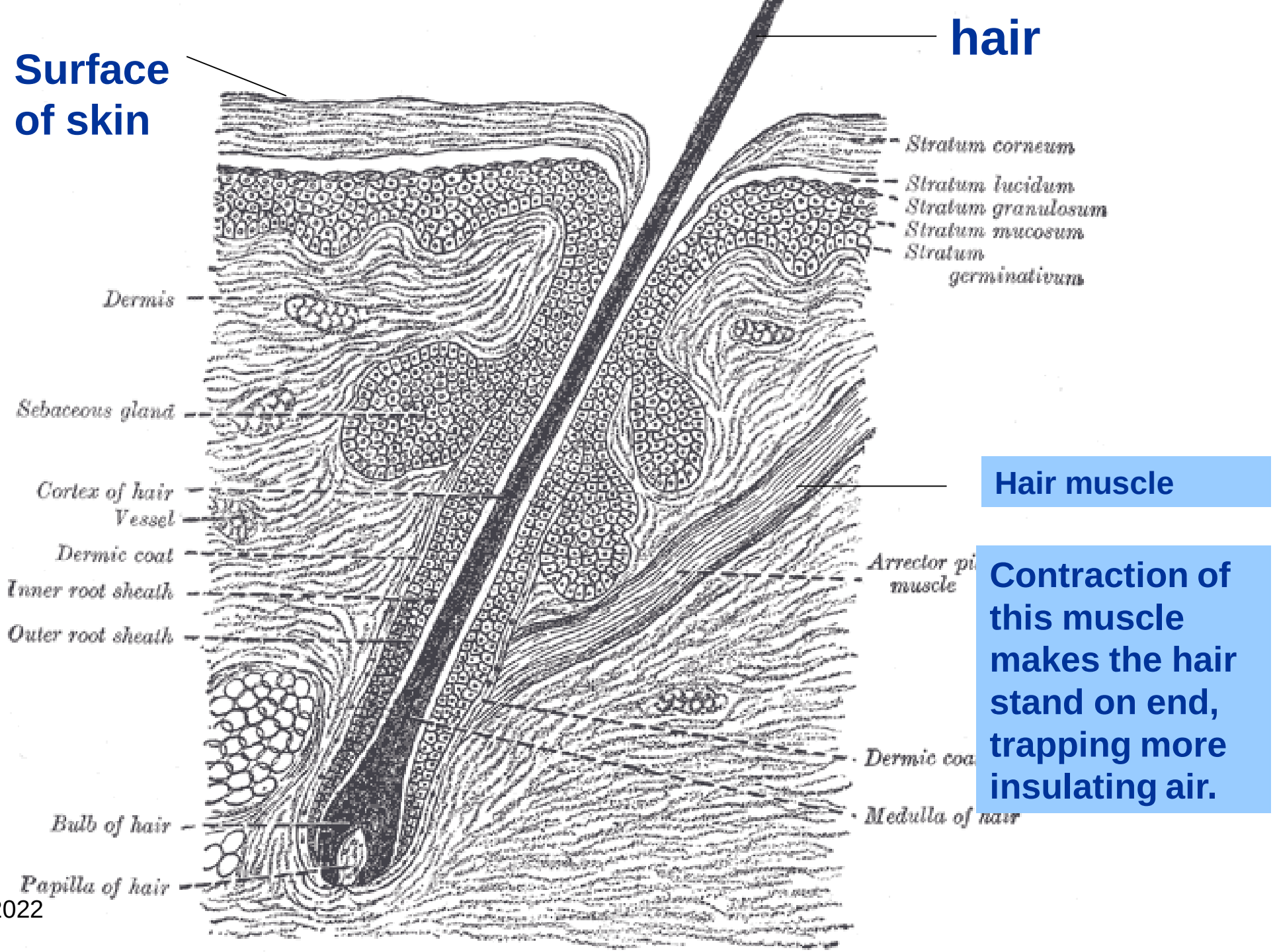
In a cold environment we need to reduce heat loss. This system is more efficient in furry animals than in humans.

Nerve impulses from the **hypothalamus** cause the **erector muscles** in our skin **contract** causing the hair (or feathers in birds) to rise up. This increases the layer of **insulating air** trapped by them so keeps the body warm.

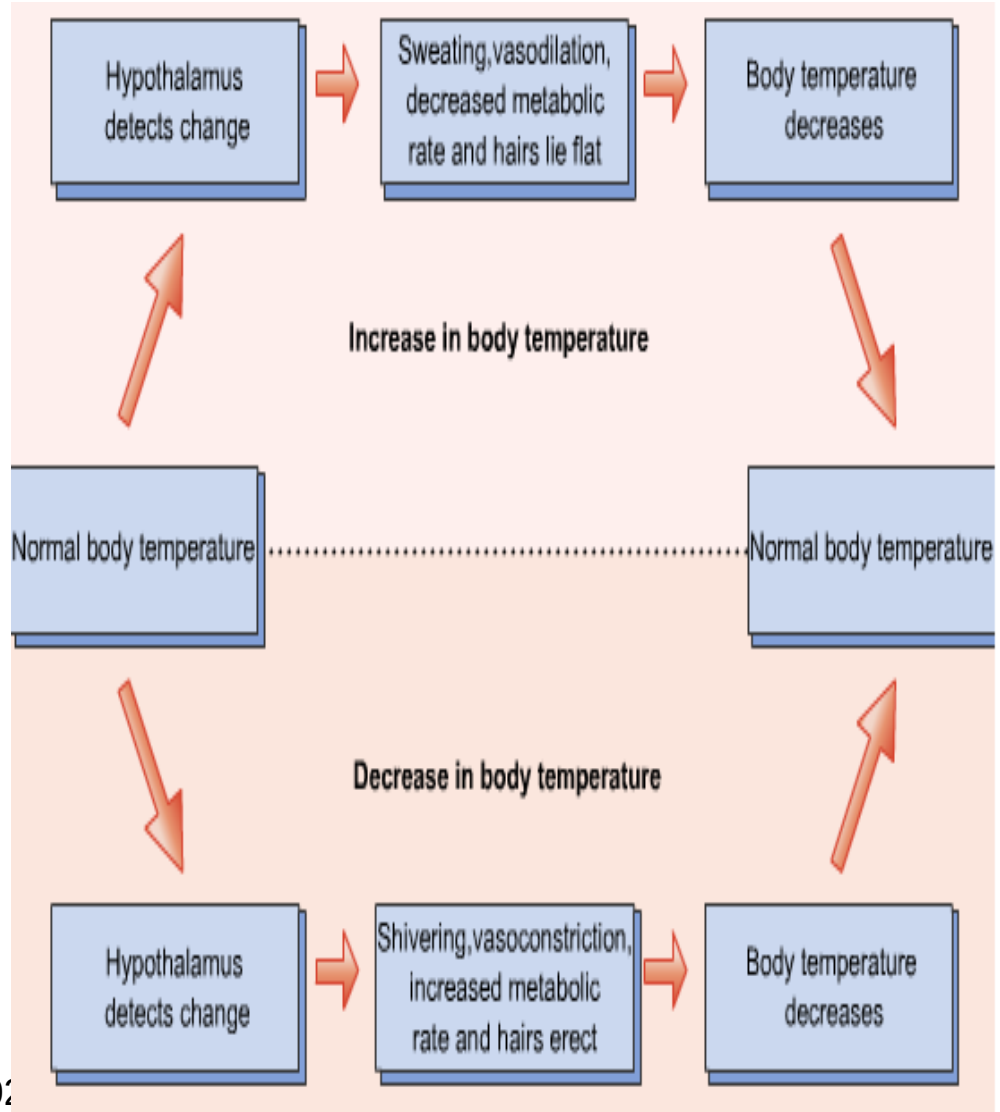
erector muscles relaxed

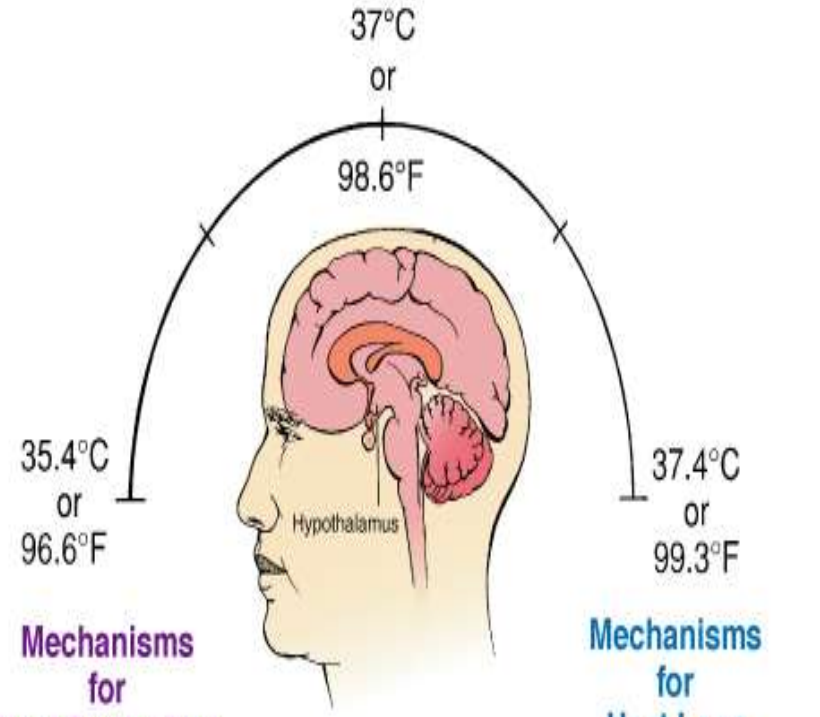


erector muscles contracted


Surface of skin
hair
Stratum corneum
Stratum lucidum
Stratum granulosum
Stratum mucosum
Stratum germinativum
Dermis
Sebaceous gland
Cortex of hair
Vessel
Dermic coat
Inner root sheath
Outer root sheath
Hair muscle
Arrector pi muscle
Contraction of this muscle makes the hair stand on end, trapping more insulating air.
Dermic coa
Medulla of hair
Bulb of hair
Papilla of hair

Summary: Body Temperature





Mechanisms for Heat Production

Vasoconstriction
Shivering
Increased activity
Huddled position
Increased metabolism

Mechanisms for Heat Loss

Vasodilation
Sweating
Reduced activity
Stretched body position
Decreased appetite

Positive feedback mechanism

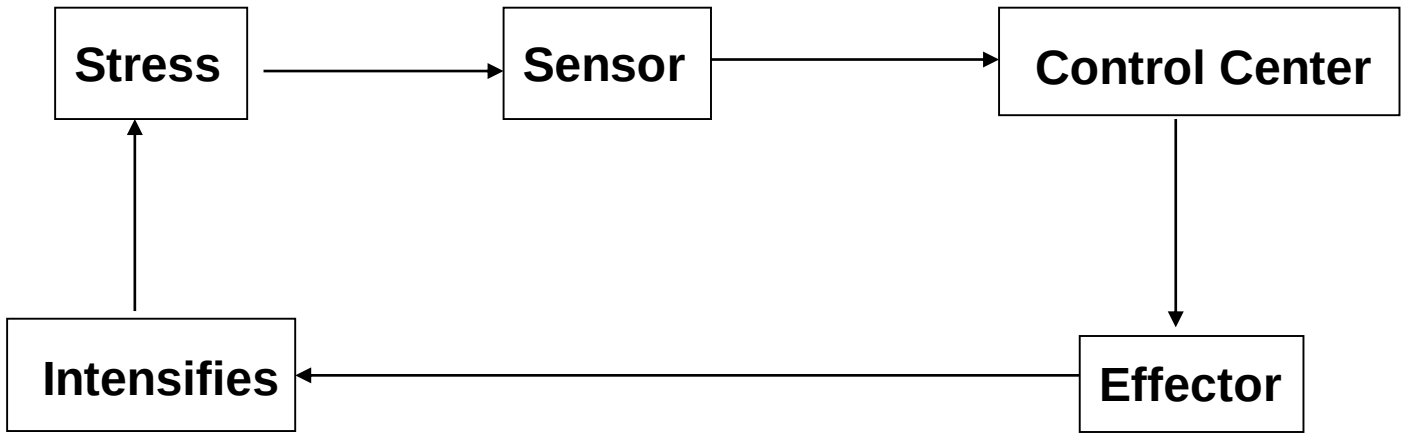
- A positive feedback mechanism enhances or exaggerates the original stimulus so that activity is accelerated
- It is considered positive because it results in change occurring in the same direction as the original stimulus
- Positive feedback mechanisms usually control infrequent events such as blood clotting or childbirth

Positive Feedback Mechanisms

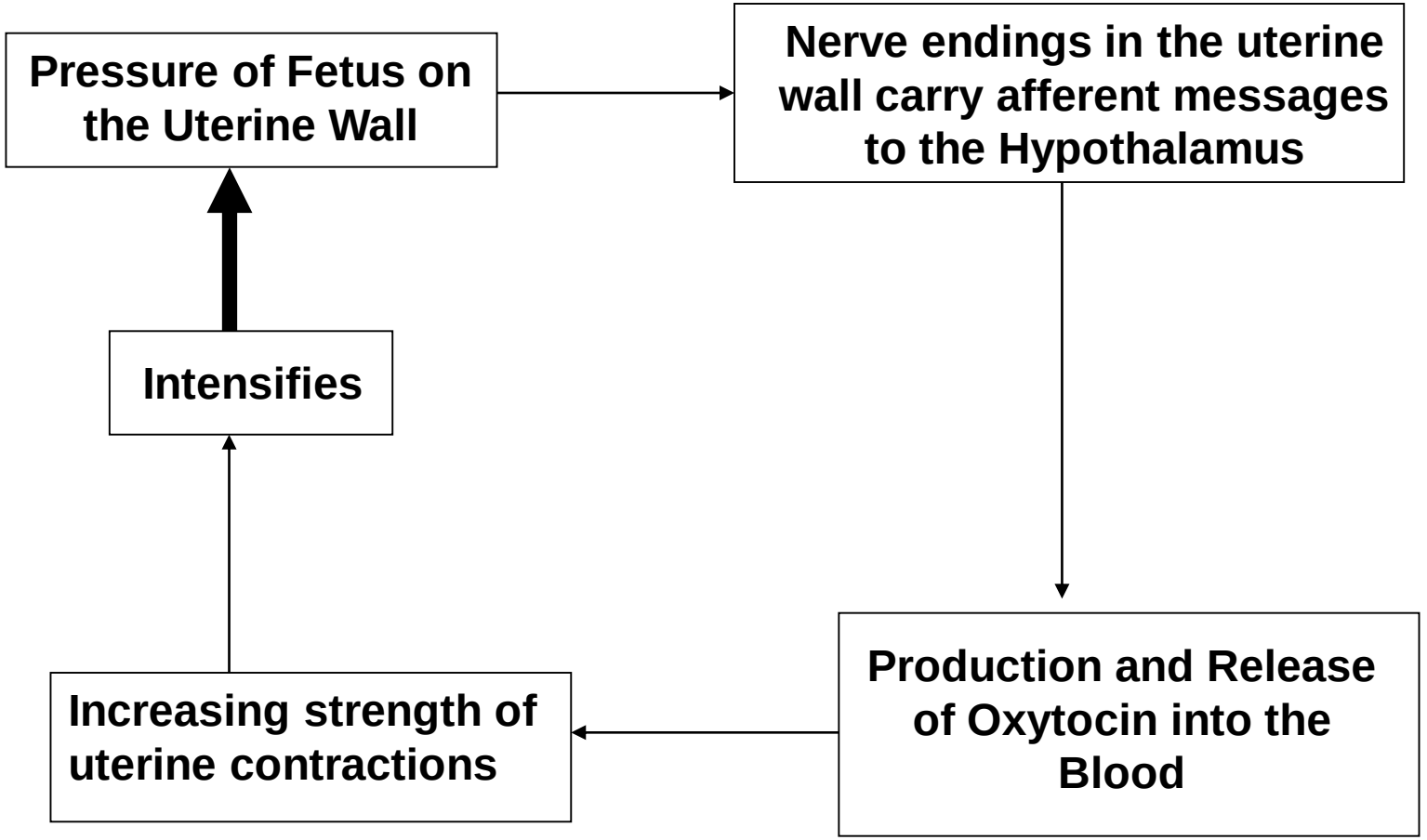
Homeostatic systems utilizing positive feedback exhibit two primary characteristics:

1. Time limitation – Processes in the body that must be completed within a constrained time frame are usually modified by positive feedback.
2. Intensification of stress – During a positive feedback process, the initial imbalance or stress is intensified rather than reduced as it is in negative feedback.

Typical Positive Feedback Process



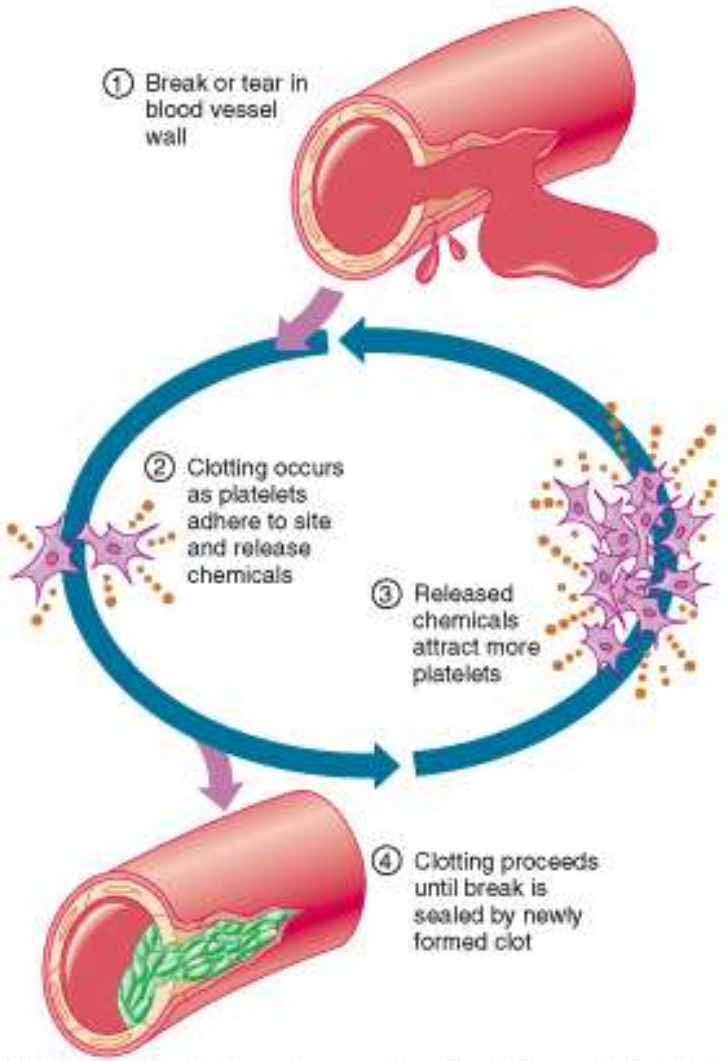
Homeostatic Regulation of Child Birth through Positive Feedback



The birth of the child will bring this process to a close. Other examples of positive feedback regulation occur during milk letdown and blood clotting.

Positive Feedback Mechanism

- Break or tear in blood vessel wall
- Clotting occurs as platelets adhere to site and release chemicals
- Released chemical attract more platelets
- Clotting proceeds until break is sealed by newly formed clot



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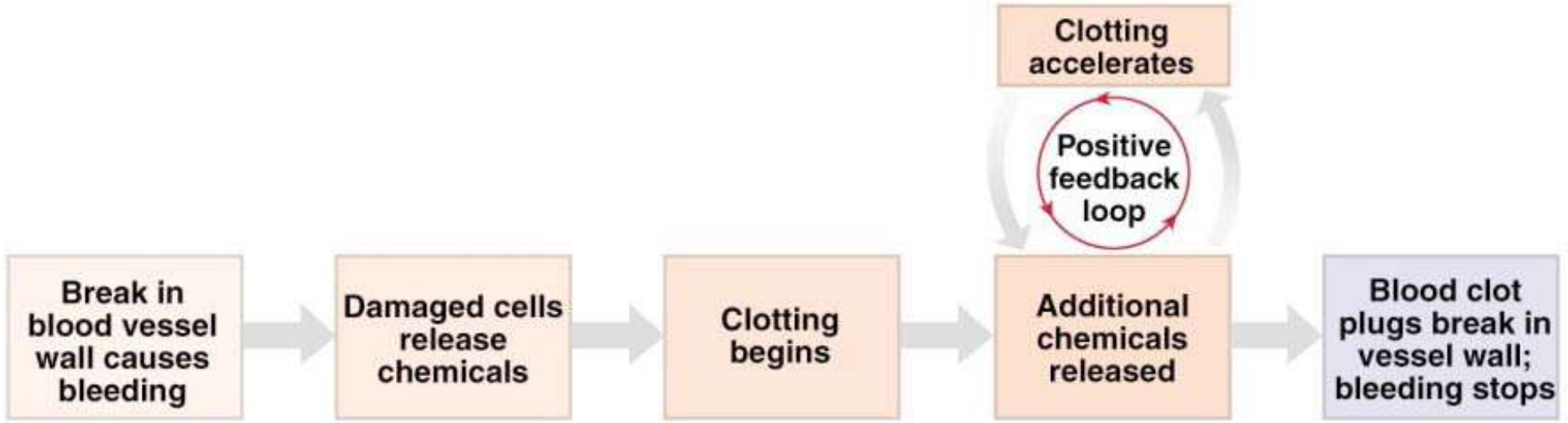
Feedback in Coagulation



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Positive feedback "mini-loops" are built into pathway to speed up production of chemicals needed to form the clot. Entire sequence of clotting is a negative feedback pathway:

Harmful effects of positive feedback

- Positive feedback can be harmful. 2 specific examples of these harmful outcomes would be:
- Fever can cause a positive feedback within homeostasis that pushes the body temperature continually higher.
- If the temperature reaches 45 degrees centigrade (113 degrees Fahrenheit) cellular proteins denature bringing metabolism to a stop and death.

- Chronic hypertension can favor the process of atherosclerosis which causes the openings of blood vessels to narrow.
- This, in turn, will intensify the hypertension bring on more damage to the walls of blood vessels.

Exercise

- 1. What is homeostasis? Why is it called a dynamic equilibrium?
- 2. Describe these components of a homeostasis loop: stress, receptor, control center, effector, response. Using an example, put them in order.
  3. What are the benefits of a negative feedback response? In what direction does a variable change as a result of a negative feedback response to a stress?