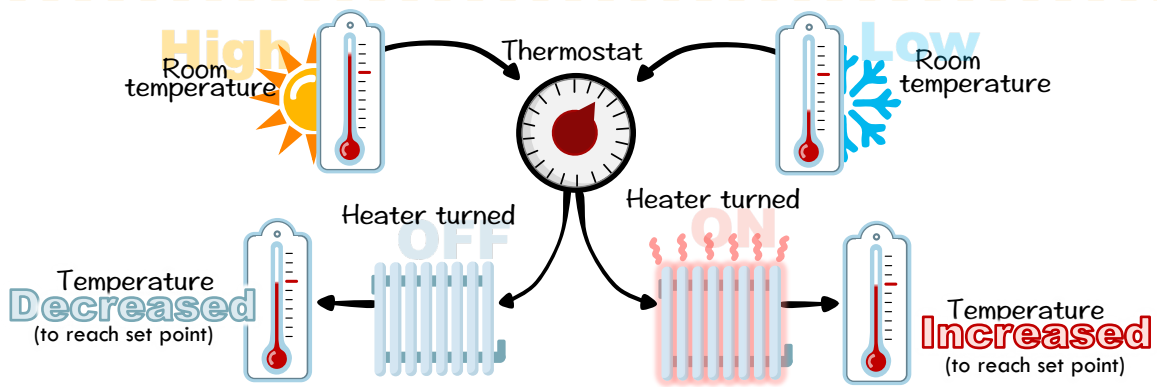
D3.3

Homeostasis

Contents

HOMEOSTASIS (Similar, Stable) – refers to an organism's ability to regulate various physiological processes to keep internal states at or near limits that are optimal.

When a certain condition gets out of its normal range, action is taken to return the condition to normal – this is called **Negative Feedback**.



A good example to illustrate this concept is a THERMOSTAT:

1. You set your thermostat at 22°C.
2. On a HOT SUMMER day, the temperature will RISE (higher than 22°C, the set point), this is detected by the THERMOSTAT which will then TURN OFF your heater to DECREASE the temperature back down to 22°C.
3. On a COOL WINTER day, the temperature will DROP (lower than 22°C, the set point), this is detected by the THERMOSTAT which will then TURN ON your heater to INCREASE the temperature back up to 22°C.

Big Brain Tip!

You can think of homeostasis as Golilocks:

Not too high blood pressure.
Not too low blood pressure.

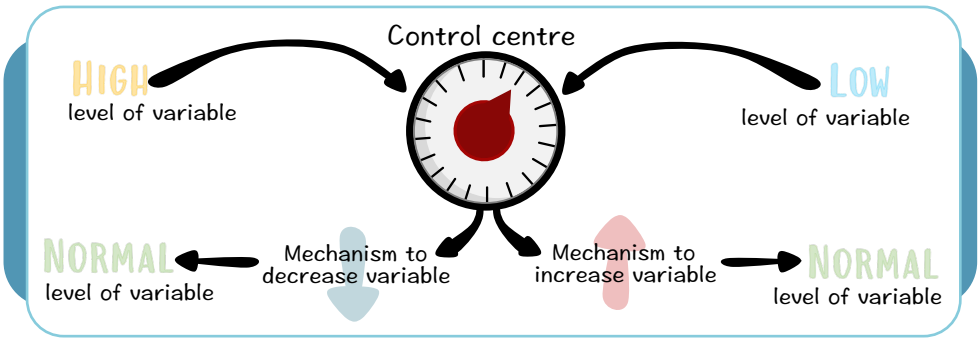
Not too high blood pH.
Not too low blood pH.

Not too much glucose.
Not too little glucose.

Not too warm.
Not too cold.

→ For the IB, you only need to focus on these two!

Any variable in your body can be considered as such:



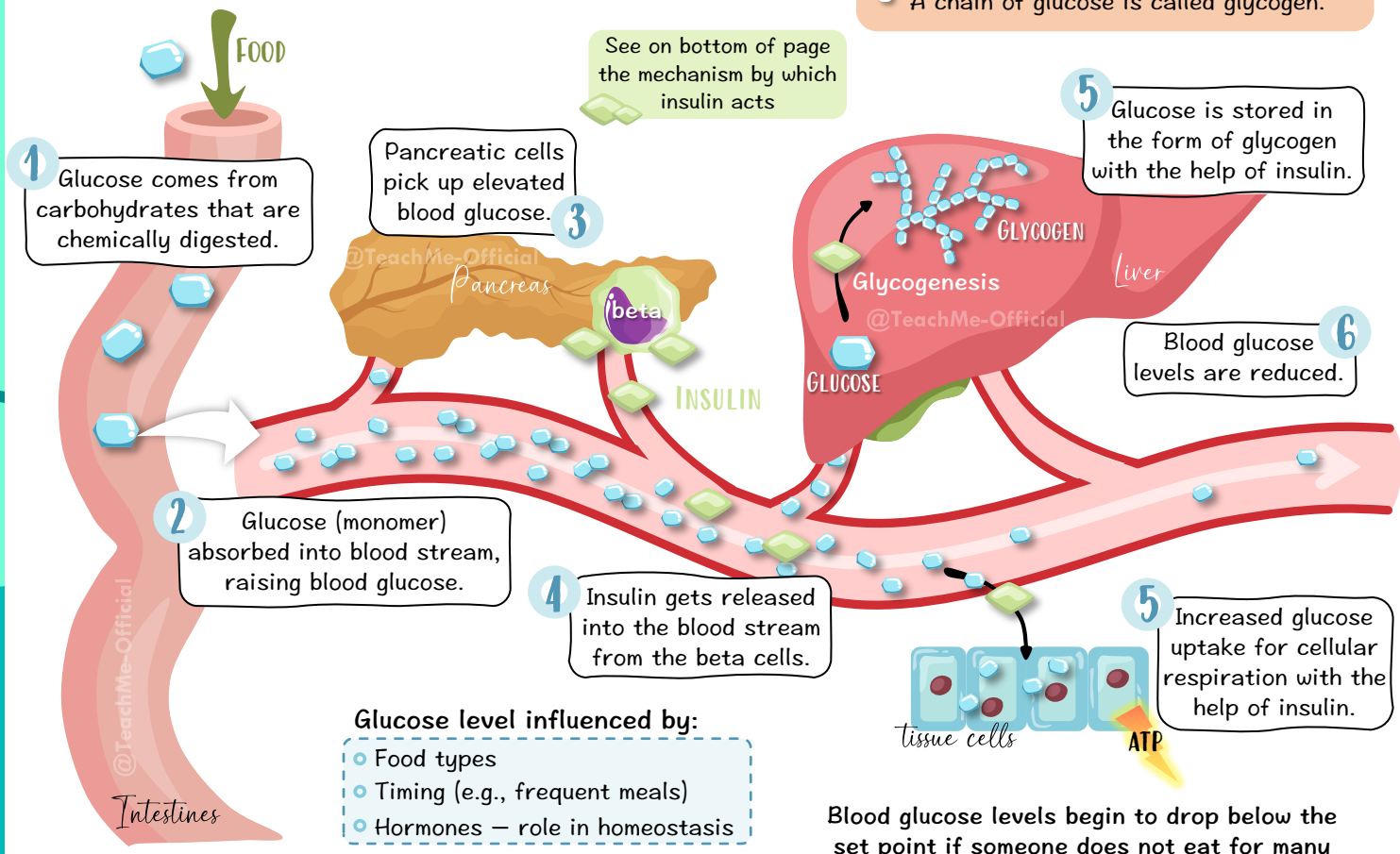
Homeostasis

I. Glucose Homeostasis

A Mechanism to decrease Blood Glucose

Big Brain Tip!

Do not confuse, GLUCOSE and GLYCOGEN. Glycogen is the storage form of glucose. A chain of glucose is called glycogen.



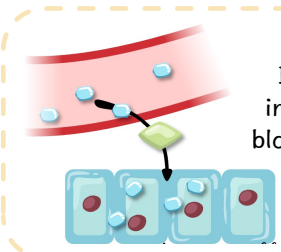
Glucose level influenced by:

- Food types
- Timing (e.g., frequent meals)
- Hormones – role in homeostasis

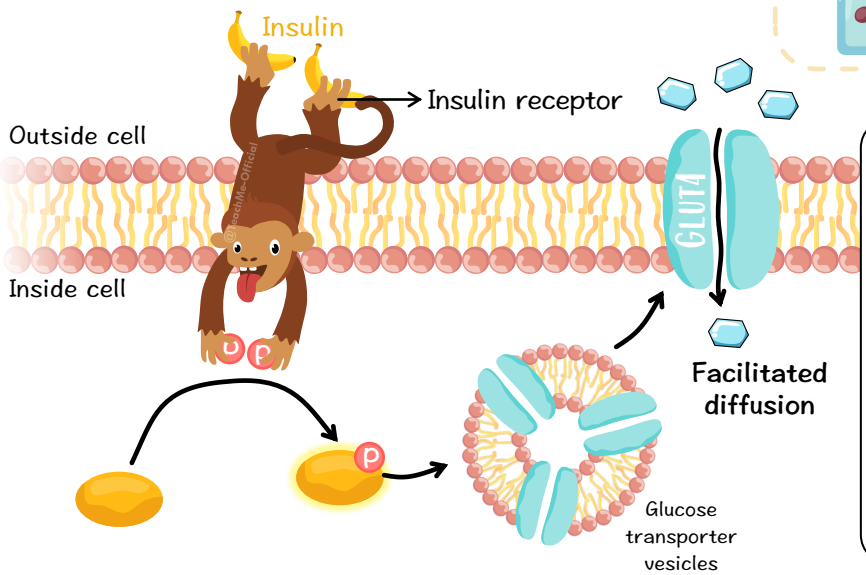
Blood glucose levels begin to drop below the set point if someone does not eat for many hours or exercises vigorously!

B Mechanism of action of insulin

NOTICE! If you are an HL student, you might remember this receptor: **tyrosine kinase receptor.**



Insulin allows cells to intake glucose from the blood, thus lowering blood glucose levels.



Summary of mechanism:

Body has excess glucose
↓
Pancreas makes insulin
↓
Insulin binds to receptor
↓
Triggers a cascade that results in glucose transporter (Glut-4) vesicles to move and merge with the cell membrane.
↓
Increase glucose uptake into cell (facilitated diffusion) and out of the blood stream.

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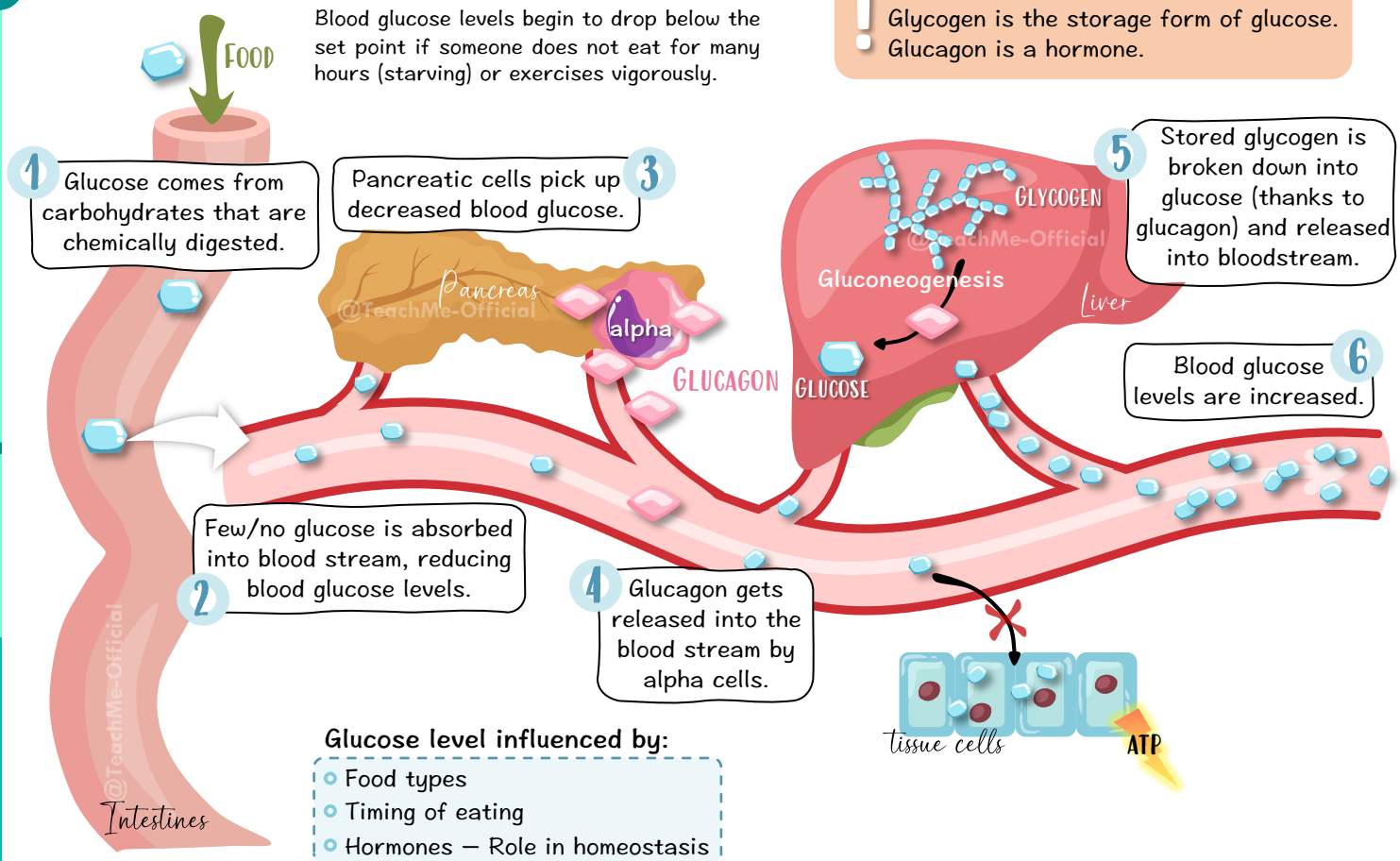
C Mechanism to increase Blood Glucose

Blood glucose levels begin to drop below the set point if someone does not eat for many hours (starving) or exercises vigorously.

Big Brain Tip!

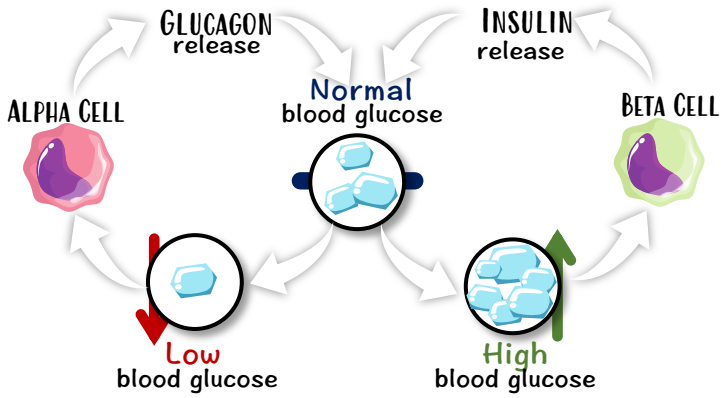
Do not confuse, GLUCAGON and GLYCOGEN. Glycogen is the storage form of glucose. Glucagon is a hormone.



Glucose level influenced by:

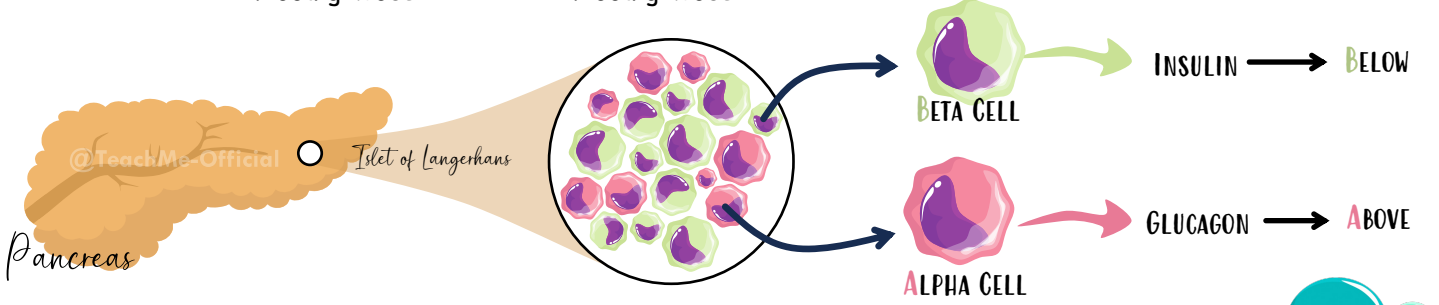
- Food types
- Timing of eating
- Hormones – Role in homeostasis

Summary of Glucose Metabolism



Negative Feedback

Occurs when the condition is not in normal range anymore and action is taken to return the condition to normal.



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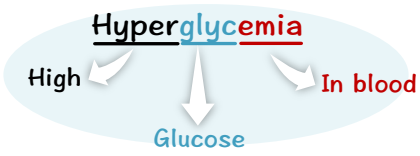
Diabetes (disease of glucose homeostasis)

Diabetes is a disease characterized by hyperglycemia.

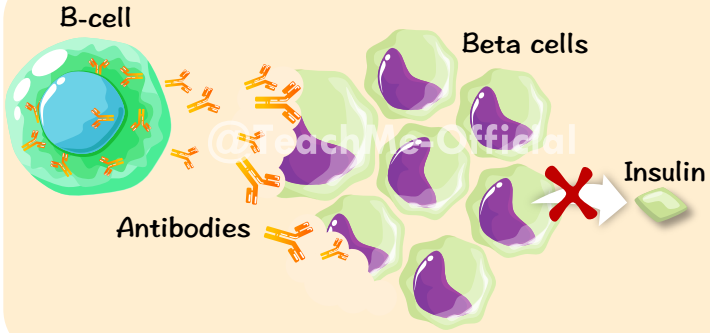


Hyperglycemia
Condition when blood sugar levels are **too high**.

Hypoglycemia
Condition when blood sugar levels are **too low**.

There are **2** main subtypes of diabetes which vary in their mechanisms but both lead to the same outcome; **hyperglycemia**.

Type I Diabetes



What: An AUTOIMMUNE DISEASE where the immune system mistakenly destroys the BETA (insulin producing) cells of the pancreas, leading to (almost) no insulin being produced.

Patient: Children or young adults (<20).

Risk factors: Family history, and age.

Symptoms: Thirst, undiminished hunger, excessive urination.

Treatment: (1) Insulin injections. (2) Diet. (3) Exercise. (4) Monitoring.

Type II Diabetes (most common)

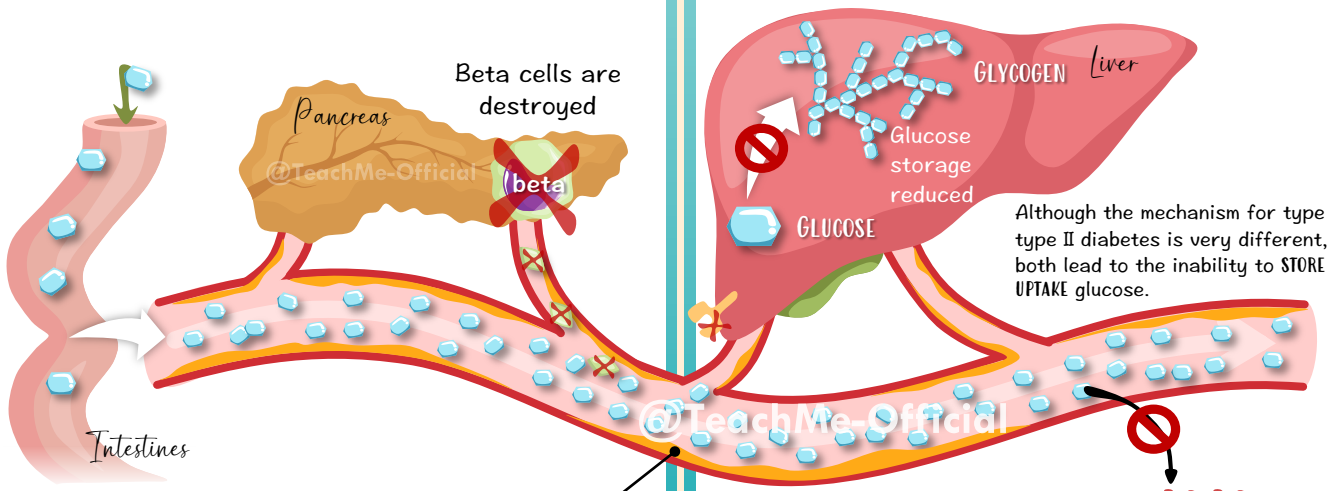
What: They can still make insulin as normal, but the body cell receptors do NOT RESPOND properly to insulin and do not take in sufficient glucose, called INSULIN RESISTANCE.

Patient: Older adults (>40).

Risk factors: Family history, obesity, lack of exercise.

Symptoms: Mild.

Treatment: (1) Insulin injections. (2) Diet. (3) Exercise. (4) Monitoring.

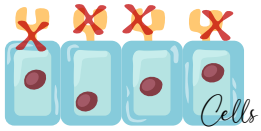


Although the mechanism for type I and type II diabetes is very different, they both lead to the inability to STORE and UPTAKE glucose.

BIG BRAIN TIP!
Type ONE = nONE (insulin)
Type TWO = FEW (insulin)

DID YOU KNOW?
Hyperglycemia causes plaque formation in arteries (which has certain consequences)

Receptors are insensitive: **insulin resistant**



UNCONTROLLED DIABETES CONSEQUENCES:

- Cardiovascular disease
- Blindless (retina damage)
- Kidney failure
- Poor wound healing
- Nerve damage

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II. Temperature Homeostasis

A Ectothermic vs. Endothermic mechanisms

There are two different ways in which organisms can regulate their internal temperature: either **ectothermically** or **endothermically**. You may have heard about these terms as "cold blooded" and "warm blooded" respectively.

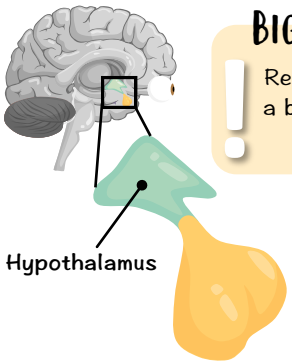
	Ectothermic (cold blooded)	**Endothermic** (warm blooded)
What	Internal body temperature equalizes with the environment.	Steady internal temperature (almost always higher than environmental temperature) despite environmental temperatures changes.
Mechanism	Air and water temperatures greatly affect the geographical boundaries for these animals. Migratory patterns in pursuit for suitable temperatures.	Body temperature is influenced by environment temperature or muscular activities. Once deviation from the set-point occurs, temperature regulating negative feedback mechanisms are activated. Sensing tissues include thermoreceptors located in the skin and a portion of the brain called the hypothalamus. Hypothalamus responds by initiating cooling mechanisms or heating mechanisms. Regulation of body temperature is called thermoregulation.
Examples	Fishes, amphibians, reptiles, & invertebrates.	Birds & mammals (like me and you).
Metabolism	No need to metabolize foods to generate body heat, hence, do not have to eat as much food.	Needs extra nutrition to generate internal body heat.

On cold days you may see these animals sunning themselves to gain body heat.

B Mechanisms to decrease Body Temperature (in endothermic organisms)

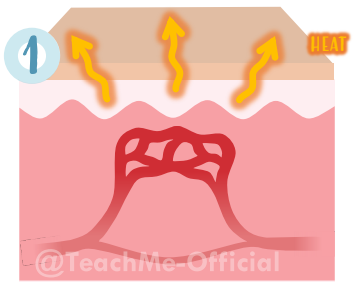
The body has a **set temperature** (e.g. in humans it ranges from 36.1°C to 37.2°C), **any** deviation away from this set temperature will trigger a response to bring it back up or bring it back down.

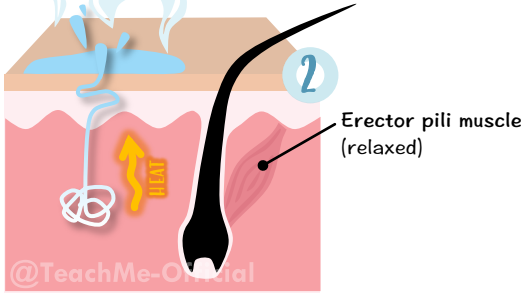
Used for instance when the environment temperature is high e.g. in the summer. The **hypothalamus** is in charge of initiating responses which aim at releasing heat, mainly: **vasodilation** and **perspiration** (sweating).



Big Brain Tip!

Remember that **heat** is a byproduct of cellular respiration.





Thermoreceptors in the skin or **hypothalamus** sense high body temperature.

1. Hypothalamus send impulses to the arterioles near the skin that result in **vasodilation**. → More blood travelling through the capillaries in the skin and more heat released into surrounding air.
2. Hypothalamus initiates **perspiration**. Heat of the body is transferred to the water in sweat, initiating the phase change of evaporation → Evaporation of sweat from the skin provides evaporative cooling.

Notice: organisms also alter their **behavior** such as removing layers of clothing, turning on a fan... although these examples might just be specific to us humans ;)

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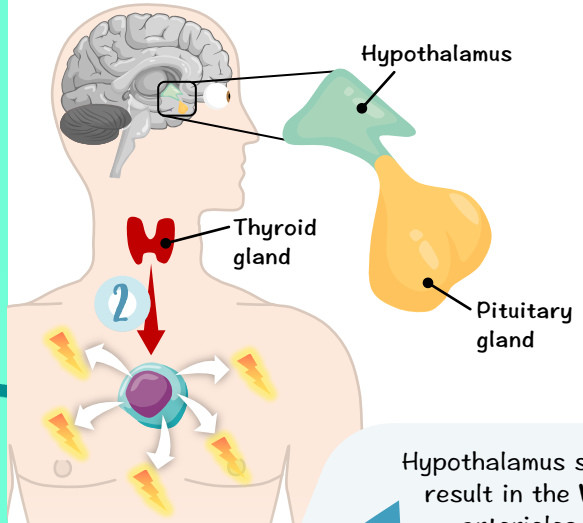
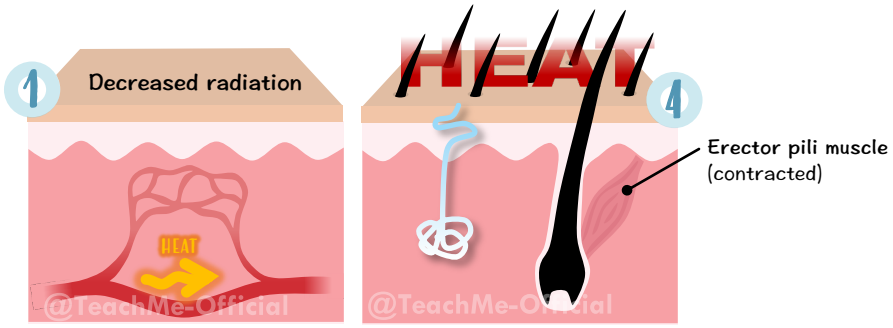
C Mechanisms to increase Body Temperature (in endothermic organisms)

Used for instance when the environment temperature is low e.g. in the winter. The HYPOTHALAMUS is in charge of initiating responses which aim at retaining heat, mainly: VASOCONSTRICTION, THYROXINE, SHIVERING and RAISING HAIRS. You may notice there are more ways in which we can increase body temperature compared to decreasing it.





Thermoreceptors in the skin or HYPOTHALAMUS sense low body temperature.

1. Hypothalamus sends impulses that result in the VASOCONSTRICTION of arterioles near the skin. → More blood shunted to internal organs, less to the skin. Less heat released to the environment.
2. Hypothalamus sends impulses to the PITUITARY GLAND which stimulates the THYROID GLAND to release THYROXINE (hormone). → Thyroxine increases metabolic rate (all body cells) to generate more heat. ATP
3. Shivering (rapid contraction of muscles) is initiated by the hypothalamus. → Shivering uses muscles to generate body heat (cellular respiration by muscles create more heat as a byproduct).
4. Stimulation of the adrenal glands leads to the release of epinephrine (adrenaline) which raises hairs on the skin (goosebumps). → In furred mammals, this response creates an insulating layer of air between the fur and skin to protect the body from the cold air.

NOTICE: organisms also alter their BEHAVIOR such as adding layers of clothing, turning on a heater, seeking warmth (e.g. burrowing), etc...

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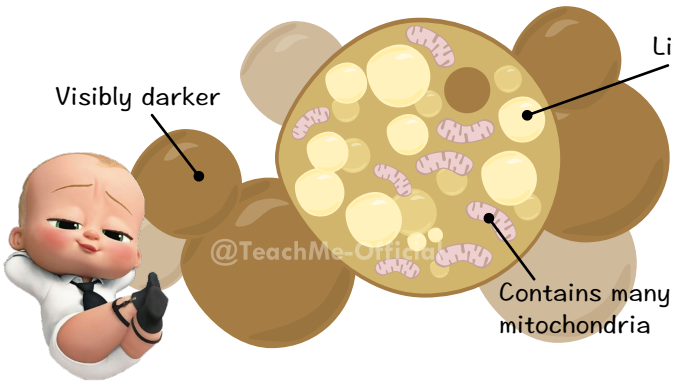
D Types of adipose tissue

Brown adipose tissue

Purpose: Heat generation



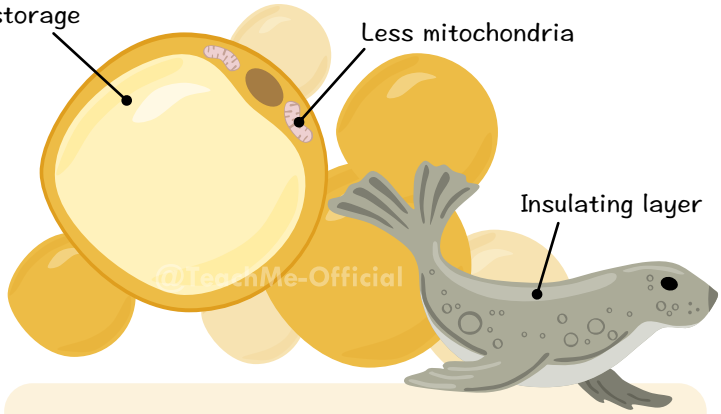
Newborns are unable to shiver, instead they have a higher proportion of brown adipose tissue (compared to adults).

When needed, the cells use their mitochondria to begin cell respiration that is uncoupled from ATP production. Glucose is oxidized for the sole purpose of GENERATING body heat.

Even though brown adipose tissue is mainly found in infants, adults retain a small amount of brown adipose tissue.

White adipose tissue

Purpose: Energy storage



Some animals have evolved to use BLUBBER (e.g. in seals) as an insulating layer between the water or air and their internal organs.

It is a form of adipose tissue and helps to RETAIN the warmth generated by internal metabolic activities.

notes