# PHYSIOLOGY OF THERMODYNAMICS AND THERMOREGULATION AS TEACHING MATERIALS PROBLEM BASED LEARNING (PBL) LEARNING METHOD

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## INTRODUCTION

The problem based learning (PBL) learning method is a learning method for students. Students will be divided into small groups, each group consisting of ten to 15 students and guided by a tutor as a facilitator. In tutorial discussions, it is necessary to appoint one person as the chairman of the discussion and one person as the secretary. The discussion leader and secretary are appointed in turn for each scenario so that all students have the opportunity to practice as leaders in discussions. Therefore it is necessary to understand and carry out the roles and tasks of each in the tutorial so that the learning objectives are achieved. Before the discussion begins, the tutor will open the discussion with introductions between the tutor and students as well as between students. The chairman of the discussion assisted by the secretary leads the discussion by using seven steps or seven jumps to discuss the problems in the scenario.
Several teaching materials are needed in the implementation of PBL. One of these teaching materials is the learning module. The learning modules presented in this section are thermodynamics and thermoregulation physiology modules.

## METHOD

General Instructional Objectives include:
1. Students can explain thermodynamics and metabolism
2. Students can explain energy conversion
3. Students can explain temperature settings
4. Students can explain heat transfer
5. Students can explain thermometry
6. Students can explain heating methods in medicine

Specific Instructional Objectives include:
1. Students can explain the definitions and factors that affect thermodynamics and metabolism
2. Students can explain the types and effects of energy conversion on the human body
3. Students can explain the center, mechanisms, and factors that influence the regulation of human body temperature
4. Students can explain the mechanisms and factors that affect the processes of conduction, convection, evaporation, and radiation
5. Students can explain the types, working principles, and benefits of thermometers
6. Students can explain the effects and uses of heat in the medical field

## DISCUSSION

Thermodynamics is the science of energy phenomena that change due to heat transfer and work done. Metabolism means "CHANGE" which is the term to identify the changes that occur in living things. Metabolism is the total number of chemical or physical reactions necessary for life. Metabolism is used in terms of denoting a series of reactions of types of food or their derivatives. Anabolism is a synthesis reaction leading to the storage/organization of energy in the body. Catabolism describes tissue degradation/breakdown of substrates and the use of energy sources (Azzolino et al., 2020) (Hidayati et al., 2023).

**Energy conversion**

Combustion with the calorimeter:

☐ Sucrose produces 3.94Kcal/gr.
☐ Glucose produces 3.74 Kcal/gr
☐ Glycogen produces 4.19 Kcal/gram
☐ Flour produces 4.18 Kcal/gr
☐ Average fat produces 9.3 Kcal/gr
☐ Protein produces 5.6 Kcal/gr

On the Human Body:

☐ Protein and carbohydrates each 4.1 Kcal/gr
☐ Fat 9.3 Kcal/gr.

**Body Temperature Regulation**

The temperature regulation of birds and mammals is physiologically classified as worm-blooded or homo-thermal. This regulatory activity is controlled by the central nervous system which controls metabolism, blood circulation, perspiration (evaporation), and muscle work. K = W/H

K = efficiency, H = total energy working time, W = work in kg M (Ganong, 2001)(Nakamura, 2011).

Temperature Setting

Regulating the temperature of heat loss and heat production. This arrangement only occurs in living things. The human body is a homoiotherm. The thermoregulatory center in the hypothalamus regulates the production and loss of heat to maintain a constant body temperature in changing environmental temperatures. Feedback mechanisms that occur as the body's response to cold, namely chills, hunger, muscle activity, constriction of skin blood vessels, wrinkled skin, raised body hair (piloerection). Feedback mechanisms that occur as the body's response to heat are dilation of blood vessels, sweating, increased breathing, decreased appetite, lethargy. Heat can enter and be lost in the environment by means of convection, radiation, and evaporation (Fisher, 2014) (Wang et al., 2011).

Conduction is the transfer of heat through a medium from high temperature to low temperature. Heat transfer due to collisions between molecules of the medium. conduction depends on the magnitude of the temperature difference and the thermal conductivity of the material. The denser a medium, the greater its thermal conductivity. Some materials such as metal are good conductors, while air is a poor conductor (Cole & Çetin, 2011).

Heat loss through radiation occurs when the air is in direct contact with the body and the temperature around the object is very low. Radiation is the transfer of heat energy from the surface of an object to another object with radiation without

experiencing contact with the object. Black bodies are very good absorbers of radiation, so they are called radiators. Heat loss through radiation occurs when the air is in direct contact with the body and the temperature around the object is very low (Ngo et al., 2015).
Heat loss through convection when the temperature around the object is lower than body temperature. Heat loss due to evaporation is between the output of skin evaporation and respiration from the lungs. Temperature 15-20C around 0.4-0.5 liters of evaporation through the skin is called insensible perspiration. Feed mechanism The reverse occurs in the mechanism of cold activity, namely chills, hunger, muscle activity, constriction of blood vessels, and wrinkled skin.
Evaporation is the transfer of heat from liquid to gaseous form. Evaporative heat loss can occur when: (1) the difference in water vapor pressure between sweat on the skin and the air; (2) the ambient temperature is lower than normal so that evaporation from sweat can occur and can remove heat from the body and that can occur if the temperature is wet-dry below skin temperature; (3) There is wind movement (4) low humidity. If the air is dry evaporation can occur, but if the air is humid, evaporation does not occur. Heat loss by evaporation is a combination of evaporation through the skin and breathing. At temperatures of 15-200C, about 0.4-0.5 liters of evaporation through the skin is called insensible perspiration. At a temperature of 70-80 F, heat loss through radiation is 60-65%, and evaporation is 20-30%.
Heat Transfers
☐ Chemical reactions in the body depend on temperature. The decrease in body chemical reactions along with decreasing temperature (Vantt Hoff's Law).
☐ Conduction is the induction of heat from an object with a higher temperature to another object by direct contact.
☐ The speed of conduction depends on the magnitude of the temperature difference and the thermal conductivity of the material.
☐ Some materials such as metals are good conductors, while air is a poor conductor.
☐ Convection is caused by the flow of hot air density which is very light compared to cold air.
☐ Radiation is the transfer of heat energy from the surface of an object to another object without experiencing contact with the object.
☐ Black bodies are very good absorbers of radiation, so they are called radiators.
☐ Evaporative heat loss can occur when: the difference in water vapor pressure between sweat on the skin and the air; the ambient temperature is lower than normal so that evaporation from sweat can occur and can remove heat from the body and that can happen if the wet-dry temperature is below the skin temperature; The presence of wind movement and the presence of moisture.

Thermometry
Objective change in temperature
☐ Types of thermometers:
1. Mercury/alcohol thermometer: The principle of expansion and contraction of the volume of mercury/alcohol due to temperature changes
2. Resistance thermometer: electronic thermometer with the working principle of the Wheatston bridge

3. Thermometer element (thermocouple): electronic thermometer with the principle of the emergence of electric force motion (emf) on two different plates that experience a temperature difference
4. Optical pyrometer: for measuring the temperature of a burning furnace, the principle of reciprocating the furnace flame with an electric lamp whose current is recorded with an ammeter
5. Contains hydrogen or helium gas: The principle of increasing and decreasing gas pressure occurs due to the expansion and contraction of gas volume due to changes in temperature. The change in pressure is held with a mercury manometer.

Heat Effect
1. Physical effect: Expansion
2. Chemical effects: Chemical reactions in the body, much depends on temperature. The decrease in body chemical reactions along with decreasing temperature (Hk Vantt Hoff).
3. Biological Effects: Combined physical and chemical effects, including vasodilation, increased blood flow, decreased blood viscosity, increased O2 and CO2 pressure, increased capillary and membrane permeability, increased white blood cells.

Heating Methods in Medicine
☐ Conduction techniques: hot water bag, hot towel, steam bath, hot mud, hot wax, electric pads (wire elements wrapped with asbestos or plastic). For the treatment of neuritis, sprains (joint trauma), strains (excessive muscle hardening in strenuous exercise), contusion (bruises), sinusitis (inflammation of the glands), Low back pain (lower back pain)
☐ Radiation Techniques: Solar radiation, infrared (incandescent lamp 250 W-1000 W and given a red filter). The waves used are between 800-40,000 nm. Energy penetration on the skin ± 3mm under the skin. More effective than the conduction method
☐ Electromagnetic Method: Shortwave diathermy, microwave diathermy, induction diathermy: with two electrodes placed side by side or winding a wire around the body part to be heated, then a high-frequency alternating current flows so that the body part is in the environmental magnetic field. For muscle cramps, intervertebral disc pain, degenerative joint disease, bursitis (inflammation of the joint bursa), inflammation of the tendons, spain, strains.

Ultrasonic Waves
☐ Ultrasonic waves are obtained from sound waves with a frequency of 1 MHz. Piezoelectric transducers are placed directly on the grid. The intensity used is about 5 watts/cm2.
☐ Ultrasound is more effective on the bone because bone absorbs more heat.

Cold Energy
☐ Cryogenics is the science and technology of using low temperatures
☐ Effects of a cold include: membrane damage, intracellular dehydration, protein denaturation, cellular hypometabolism, local ischemia, cessation of bleeding (hemostasis), anesthesia, preservation
☐ Usage: Storage, pain treatment, cancer surgery.

Thermoregulation
Thermoregulation is the ability of the body's vital autonomic nervous system to respond to cold and heat stress. Body temperature has 2 components, namely core body temperature and body peripheral temperature. Core body temperature is measured from trunk and head temperature, while peripheral body temperature is measured from extremity temperature. The core body temperature tends to be more stable and in moderate environmental conditions, the peripheral temperature is 2-4 degrees lower than the core body temperature. 16 Thermoregulation works by keeping the core body temperature within 1-2 degrees of 370C to keep cells functioning normally. Heat is produced and removed from the body so that the body remains in a state of normothermia.

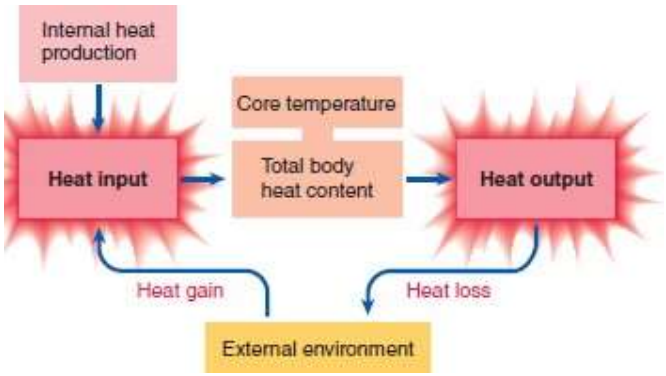


Figure 1. Body thermoregulation (Sherwood, 2008)

Core body temperature is a reflection of the total heat in the body. Heat input must be balanced by heat output to maintain a balanced core body temperature. Heat input comes from the external environment and internal heat production. Under normal conditions, there is more heat energy than the body needs, so the body has a heat output mechanism to maintain the body's core temperature.

Thermoregulatory physiology
Like other systems, the physiological regulation of body temperature requires the presence of afferent systems, control centers, and efferent systems.The first system, afferent, is responsible for capturing information via skin receptors. Next, information is transmitted to the thermoregulation center nervously via the blood. Under normal conditions, the organs that produce heat are the heart and liver. When the body does physical work (exercise), the skeletal muscles are also heat-producing structures. the hypothalamus is the center of thermoregulation and its tasks are divided into heat loss and heat gain. The functional zone to mediate heat maintenance is located in the posterior zone of the hypothalamus, whereas loss is mediated by the anterior region. This organ works like a thermostat. System control occurs in two ways: positive and negative, mediated by the cerebral cortex. Effector responses are a type of behavior or are mediated by the autonomic nervous system (Kurz, 2008) (Morrison & Nakamura, 2019).

Thermoregulation mechanism

The mechanism of temperature regulation differs between the types of stimuli received, namely an increase or decrease in temperature. So we will use these parameters to classify the mechanisms:

Regulation for high temperature

To achieve regulation of body temperature in the face of heat stimulation, the body must increase its loss. There are several mechanisms:

Vasodilation

In humans, one of the most striking features of the circulatory system of the skin is the wide range of blood vessels it has. Circulation of blood through the skin varies greatly depending on environmental conditions and changes from high to low blood flow.

Vasodilating ability is very important in individual thermoregulation. High blood flow during periods of increased temperature allows the body to increase heat transmission, from the body core to the surface of the skin, where it is finally dissipated.

When blood flow increases, skin blood volume increases in turn. Thus, more blood is transferred from the core of the body to the surface of the skin, where heat dissipation occurs. The blood that is now cooler is transferred back to the core or center of the body.

Sweat

Along with vasodilation, sweat production is essential for thermoregulation because it helps dissipate excess heat. In fact, the production and subsequent elimination of sweat is the body's primary mechanism for heat loss. They also work during physical activity. Sweat is a liquid produced by sweat glands called eccrine, distributed throughout the body in significant density. Evaporation of sweat moves heat from the body to the environment as water vapor (Romanovsky, 2018)

Regulation for low temperature

In contrast to the mechanisms mentioned in the previous section, in a situation of reduced temperature, the body must increase the conservation and production of heat in the following ways:

Vasoconstriction

This system follows the counter-logic described in vasodilation, so we won't go into much detail in its explanation. Cold stimulates the contraction of skin vessels, thereby avoiding heat.

Piloerection

Have you ever wondered why "goosebumps" appear when we are in front of low temperatures? This is a mechanism to prevent heat loss called piloerection. However, because humans have relatively little hair on our bodies, it is considered an ineffective and rudimentary system. When the height of each hair occurs, the layer of air in contact with the skin increases, which decreases air convection. This reduces heat loss.

Heat production

The most intuitive way to combat low temperatures is to generate heat. This can occur in two ways: by shivering and non-shivering thermogenesis.In the first

case, the body produces rapid, harmless muscle contractions (which is why you shiver when you're cold) which leads to heat production. Production of chills is expensive – passionately speaking – so the body will fall back if the aforementioned systems fail.

The second mechanism is led by a tissue called brown fat (or brown adipose tissue, in the English literature usually summarized under the acronym BAT for brown adipose tissue). This system is responsible for breaking down energy production in metabolism: instead of forming ATP, it leads to heat production. This is a particularly important mechanism in children and small mammals, although more recent evidence has found it to be relevant in adults as well (Park, 2015).

Thermoregulation disorders

The body goes through small and subtle changes in temperature throughout the day, depending on several variables, such as circadian rhythms, hormonal cycles, among other physiological aspects. As we mentioned, body temperature regulates a large number of physiological processes and loss of regulation can cause devastating conditions within the affected organism. Both thermal extremes – both high and low – negatively affect organisms. Very high temperatures, above 42 ° C in humans, have a very pronounced effect on proteins, promoting their denaturation. In addition, DNA synthesis is also affected. Organs and neurons are also damaged (Zawadzka et al., 2017).

Similarly, temperatures below 27°C cause severe hypothermia. Changes in neuromuscular, cardiovascular, and respiratory activity have fatal consequences.Several organs are affected when thermoregulation does not work properly. This includes the heart, brain, digestive tract, lungs, kidneys, and liver (Lu et al., 2021).

## CONCLUSION

The thermodynamics and thermoregulation modules can be used as teaching materials for PBL learning in related scenarios.

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