ADAPTATION TO HIGH AND LOW AMBIENT TEMPERATURES

Introduction

- Ambient temperature(temperature of the immediate surroundings or environment).
- Low ambient temperature is the low surrounding temperature while high ambient temperature is the high surrounding temperature of an organism in its environment.

PHYSICAL PRINCIPLES IMPORTANT IN THERMOREGULATION

THEMOREGULATION: It is the maintenance of a constant body temperature of an organism.

- Here we have the poikilotherms (cold blooded animals) whose body temperature varies with that of environment and homeotherms (warm blooded animals)who posses internal mechanism to maintain body temperature.
- Some definitions:

Heat: It is the spontaneous flow of energy from one object to another cause by a difference in temperature between 2 objects.

- **Temperature**: It is the degree of hotness or coldness of a body or environment. it is usually measured in degrees Celsius(^{0}C)
- **Specific heat**: It is the heat in calories required to raise the temperature of 1 gram of a substance 1 ^{0} C.
- **Heat capacity**: It is the ratio of heat energy absorbed or required by a substance to increase its temperature. It is also called thermal capacity.
- **Specific heat capacity**: It is the amount of heat needed to warm 1g of a substance by 1^{0}C. Specific heat capacity of water is 1.0 calg^{-1}^{0}C^{-1} which is high as compared to other substances

- **Energy exchange** (heat transfer) is essential in physiological mechanisms involved in the regulation of heat production and heat loss.
- **Avenues of energy exchange** include; radiation, conduction, convection and evaporation between animals and the environment.
- **Radiation** where heat transfer takes place in the absence direct contact between objects but by means of electromagnetic energy which travels at speed of light.

Ex. human skin absorbs virtually 100% of incoming infrared radiation and thus is a black body in these wavelengths.

- **Conduction** of heat takes place between physical bodies that are in contact with each other. Ex. a cold fluid is in contact with a warm solid surface.

- **Convection** is the process which invariably accelerates the transfer of heat in fluids. Ex. if a warm solid surface is in contact with a cold fluid, the heated fluid expands and rises, being replaced by cool fluid. Hence the mass flow or convection is caused by temperature difference.
- **Evaporation** is a process which involves the conversion of a liquid(water) to vapour or gas. Ex. when a man is exposed to hot surroundings, he cools himself by evaporation of sweat.

If air temperature exceeds the body surface temperature, heat will flow to the body by conduction, convection and radiation.

ECTOTHERMY TO PARTIAL ENDOTHERMY

- **Ectothermy** is a term which describes animals that depend on external heat sources primarily solar radiation to maintain their body temperature hence ectotherms.
- Whereas endothermy refers to animals able to maintain a high body temperature by internal heat production i.e producing heat within their own tissues to thermoregulate.
- Most reptiles are ectotherms and as concerns thermal adaptation, many reptiles utilize sensitive infrared receptors to discover either warm or cold places.

- **Q_{10} defined**

Q_{10} is the increase in a rate caused by 10^{0}C increase in temperature. Q10 is used not only for oxygen consumption but for all rate processes affected by temperatures.

- **Thermal preference in fish.** If bullheads are given the opportunity to select their own preferred water temperature by presenting them with a temperature gradient, the water temperature they select depends on their previous thermal history.
- **Maintaining temperature by adjusting behavior** Example: the horned lizard during day and night.
- **Partial endothermy** It occurs in ectotherms which have relatively large mass (tuna and python).

The arterial blood from the gills is at water temperature and as it runs in the fine arteries between the veins, it picks up heat from venous blood that comes from the muscles.

The venous blood on reaching the larger veins under the skin, losses its heat, which is returned to the muscle via arterial blood. As a result, the tuna can maintain muscle temperatures .

Female python coils herself around the eggs and as air temperature is lowered, she increases her rate of oxygen consumption and keeps her body temperatures above that of the air. It is caused by strong muscle contractions.

True Endotherms

- Some animals maintain a high body temperature by internal heat production or metabolism. As concerns the relationship between Ta and metabolism in endotherms, there is temperature regulation by keeping warm in the cold and by keeping cool in the heat.
- **Lower and upper critical temperatures**

It is noticed in the pygmy possum that below a certain Ta (lower critical temperature) metabolic rate increases linearly with decreasing temperature and at the upper critical temperature, heat production remains constant as temperature is increased.

- **zone of thermoneutrality.** Here metabolic heat production is unaffected by a temperature change.

- **Responses to cold: Heat Production**

3 major ways in which heat production is increased;

i. Muscular activity and exercise
ii. Involuntary muscle contractions (shivering)
iii. So called non shivering thermogenesis (NST).

Shivering in mammals and birds, the response to the cold are mediated by the sympathetic system where a shivering center in the hypothalamus is activated which in turn activates brainstem motor centers to initiate involuntary contraction of skeletal muscles, causing shivering and generating a lot of heat.

- **NST** is an increased metabolic rate that takes place without noticeable muscle contractions. For an animal exposed in the cold there is a certain amount of heat loss. The lower the ambient temperature, the greater the increase in metabolic rate needed to stay warm.

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- **Fever** is an increase in body temperature that usually is associated with bacterial or virus infection. Pyrogen is the substance that cause of the fever reaction.
- The organism behaves as if the set point of a thermostat has been increased by a few degrees and now regulates as if to maintain the increased temperature.
- If a person with fever is challenged with cooling, increased heat production serves to maintain the higher temperature and vice versa if an extra heat load is applied.
- **Brown adipose tissue** (BAT)**.** Source of NST

Brown fat has a high content of cytochrome and can consume oxygen at a high rate while white fat is metabolically rather inactive.

The brown tissue cells are filled with fat packed with large mitochondria that gives it its characteristic color in contrast to white fat cells.

- **Responses to cold: methods of heat conservation**

Animals can conserve heat through reduction in blood flow and cooling of the arterial blood in a heat exchanger.

- Increased metabolic rate in order for heat production to balance amount of heat loss in cold.
- Again, some animals could increase their body insulation to reduce heat loss.
- **Regional heterothermy**

Thermal gradient along the limb or other extremity of an animal.

The **counter current heat exchanger in animals reduces heat loss**. EX. circulation in the human arm where heat exchange takes place between main arteries and the adjacent veins, located deep within the tissues. In cold surroundings most of the venous blood from the limbs returns in these deep veins. The warm arterial blood exchanges heat to the returning venous blood and little heat is lost on reaching the periphery.

- **Differences in insulation**

The role of fur and feathers in terrestrial endotherms is to insulate them in response to cold periods. The fur and feathers are major barriers to heat flow.

- The nearly bare areas containing short fur can potentially transfer much more heat than the heavily furred areas with longer furs.
- The bird reduces conductance (increases insulation) by raising the feathers and drawing the feet up into the feathers, thus making the body into a round feather ball.
- **Subcutaneous fat** (blubber) in aquatic endotherms (such as the seals and whales) afford their major insulation in water. The temperature gradient in this aquatic endotherm is sustained by this subcutaneous fat.

- **Daily torpor** is a physiological state in which an animal becomes inactive or less active with decreased body temperature and metabolic rate only for some hours. Ex. Bats hummingbirds.
- **Hibernation** is a physiological state in which an animal becomes less active or inactive with decreased body temperature and metabolic rate for long period of time during unfavourable conditions.

Characteristics of hibernation

1. Decreased body temperature.
2. Reduced metabolic rate.
3. Reduced heart rate and respirations.
4. There is also little response to external stimuli such noise and being touched.

The **entering into hibernation** can result from drop of MR followed by drop in Tb

- **Arousal** is an active process that requires a considerable period until the body temperature has reached normal.
- **Responses to heat**

Most mammals and birds response to heat by evaporation of water, sweating, panting, gular flutting, salivating and licking, hence keeping cool.

Sweating commonly occurs in humans possessing sweat glands to increase cooling by evaporation.

Panting is a very rapid, shallow breathing that increases evaporation from upper respiratory track. It occurs in animals with few sweat glands such as in dogs, in order to be cool. It also occurs in a number of small ungulates such as sheep, goats and small gazelles.

Gular flutter is the rapid oscillation of the thin floor of the mouth and upper part of the throat and it is used to increase evaporation particularly in birds which have no sweat

- **Hyperthermy**: is when the body temperature of an animal is above the normal. There is increase in metabolism, heart rate, strengthen muscle contractions, increase nerve conduction. This situation can lead to death in most endotherms.
- **General responses in large and small mammals**

Camels will bask in early morning sun while small rodents will get a significant heat input by crouching against east facing sun-warmed rocks to gain heat by conduction.

The camel uses less water than some other mammals due to its high body temperature and the presence of thick fur with a high insulation value and hence reduces heat gain from the environment.

In small mammals (rodents), they are unable to remain for long above the ground during a hot day. After being heated up, they go back into their holes or burrows. Ex. Ground squirrel.

Neural integration of Body temperature

- **Hypothalamus** is the seat for several nervous control functions notably temperature regulation and the regulation of intake of water and food.

It is a feedback system in control of body temperature.

- It is only one centre of integration which is the CNS (brain and spinal cord) which accepts, integrates and interprets information from all the senses.
- **Set point theory.** In a regulatory system, set point is the threshold sensitivity to the feedback stimulus.
- Experimental set-up described for set point. Regulation of central heating in a house. Air conditioning is introduced during summer in the house.

- **Experimental evidence for set point in dogs**

If the blood in carotid artery of a dog is heated, it causes the dog to pant hence loses too much heat and its core temperature drops. Alternatively, if the carotid blood is cooled, the dog begins to shiver, and the body core temperature rises. The exact location of heat regulation center can be pinpointed by heating or cooling small areas in the hypothalamus. The heat regulation center can be the thermostat and normal body temperature as the set-point.

- **Super cooling**

It is the lowering of the temperature of a fluid to below its freezing point without formation of ice.

It is a situation that occurs when an animal is exposed to a temperature considerably below the point where its body fluids might freeze.

- Freezing depends on temperature, presence of nuclei for ice formation and time.
- Super cooling in arctic fish is of great importance to its survival.
- The fish in the arctic waters are not freeze-tolerant, and so any formation of ice leads to destruction of the frozen areas and if freezing extends to vital organs, the fish rapidly dies.
- the blood and tissue fluids of the fish contain antifreeze compounds that lower the freezing point without affecting the melting point.
- The **antifreeze protein** and **glycoprotein** acts by preventing the addition of water molecules to the crystal lattice of ice, hence preventing ice formation from spreading.

- The structure of an antifreeze isolated from a fish

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