BIOL 454
ENVIRONMENTAL PHYSIOLOGY
(PART I)

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What is Environmental Physiology?

- It is the branch of biology that deals with how organisms use their physiological mechanisms to respond and adapt to changes in environmental conditions.
- How biological functions of an organism relates to their environment.
- the study of physiological adaptation or adjustment to the environment

ENVIRONMENT

- Aggregate of surrounding things, conditions or influence.

- **ASPECTS OF THE ENVIRONMENT**
- Light
- Temperature
- Water
- Altitude

The environment, however, is rarely constant even over the *short-term*.

Temporal Variation : daily and seasonal variation exist in many environmental factors (e.g., light, energy, temperature, moisture) and animals must respond to this variation in order to survive and reproduce

Spatial Variation : multitudes of habitats and microhabitats exist, even within a given environment or geographic area.

- Animals occupy most of the available habitats throughout the world, so they must show a wide variety of physiological adaptations allowing them to inhabit the conditions present.

- Many of these habitats and microhabitats are potentially stressful to the organism, at least at some times

- **PLANTS**
  - **LIGHT**
    - Leaf area
    - Day length sensitivity
    - Reflection
    - Transmission
  - **TEMPERATURE**
    - Open stomata
    - Evapotranspiration
    - Wilting

- **ANIMALS**
  - **Light** (photoperiod or day length)
    - Pineal gland
    - Reproduction and mating behaviour
      - Birds
      - Sheep
    - Large ungulates (rutting, heat)
    - Feeding behaviour
    - Hibernation
    - Antler growth

HOMEOSTASIS

- Cells of the body are designed to serve a purpose/role
- These specialized cells function are possible only when extracellular conditions are kept within limits(narrow limits)
- Conditions as concentration of Oxygen, glucose e.t.c. must be held constant for cells to function efficiently and interact properly with others
- Conditions within an organism is dynamic-fluctuating continuously within narrow limits

- Cells within the body must remain bathed in fluid that offers nutrients and carries away metabolic wastes.
- The fluid around the cells is **extracellular fluid**.
- Much of it is **interstitial**-it occupies spaces between cells and tissues. The remainder is **plasma**-fluid portion of blood
- Interstitial fluid exchanges substances with cells it bathes and with blood.

- Each cell of the animal body engages in basic metabolic activities that ensure its own survival
- The cells of a given tissue perform one or more activities that contribute survival of the whole organism.
- *The component parts of every animal work together to maintain the stable fluid environment that all of its living cells require*
- The combined contributions of individual cells, tissues, organs and organ systems that are engaged in a division of labor help maintain a stable internal environment.

- **HOMEOSTASIS**
- The tendency of a physiological system to maintain internal stability owing to the coordinated response of its parts to any disruptive stimulus

- **HOMEORHESIS**
- The coordinated response of a physiological system to support a new or altered physiological state.

Principles of Homeostasis

- **HOMEOSTASIS** is a state in which the vertebrate body maintains relatively constant internal conditions for proper functioning of body systems

- The state in which physical and chemical aspects of the internal environment (blood, interstitial fluid etc.) are being maintained within ranges suitable for cell activities.

- Homeo ⟶ same; stasis ⟶ standing still

- All the systems of the human body are involved, with particular contributions by the endocrine, nervous, respiratory, and renal systems

- Once homeostasis is maintained, an organism is generally said to be healthy.

- An organism is said to be in a state of homeostasis when its internal environment;
  - Contains the optimum concentration of gases, nutrients, ions and water
  - Has the optimum temperature
  - Has the optimum pressure for the health of the cells

- Homeostasis is essential for life and most of the mechanisms not devoted to reproduction are concerned with maintaining homeostasis.
- When it is disturbed ill health may result
- If body fluids are not eventually brought back into balance, death may occur

Why the routine examinations?

- Homeostasis in all organisms is disturbed by **stress**
  - **Any stimulus that creates an imbalance in the internal environment**
  - **Any environmental factor potentially unfavourable to living organisms**

❖ Source
  ❖ External: heat, cold, noise or lack of oxygen
  ❖ Internal: high blood pressure, tumor, pain, unpleasant thoughts

❖ Most stressors are mild and routine however, over-exposure, severe infections and surgical operations are examples of severe stress

Maintaining Homeostasis

- It is achieved through regulatory mechanisms, eg;
  - regulating level of glucose in the blood
  - regulation of body temperature

- In nearly all animals, three components interact to maintain homeostasis
  - Sensory receptors
  - Integrators and
  - Effectors

- **Sensory receptor**:- these are cells or cell parts that detect stimuli (specific forms of energy)

- These receptors are classified based on the types of stimulus they can detect;
  - Thermoreceptors-sensitive to heat or cold
  - Mechanoreceptors-detect changes in pressure, position
  - Pain receptors-detect injury

- Chemoreceptors-detect chemical energy of substances dissolved in the fluids that bathes them
- Osmorecptors-detect changes in the solute levels of body fluid
- Photoreceptors-respond to the energy of visible and ultra violet light

- **Integrator:-** a central command post that pools together information about stimuli and issues signals to the muscles, glands or both. e.g. brain or spinal cord

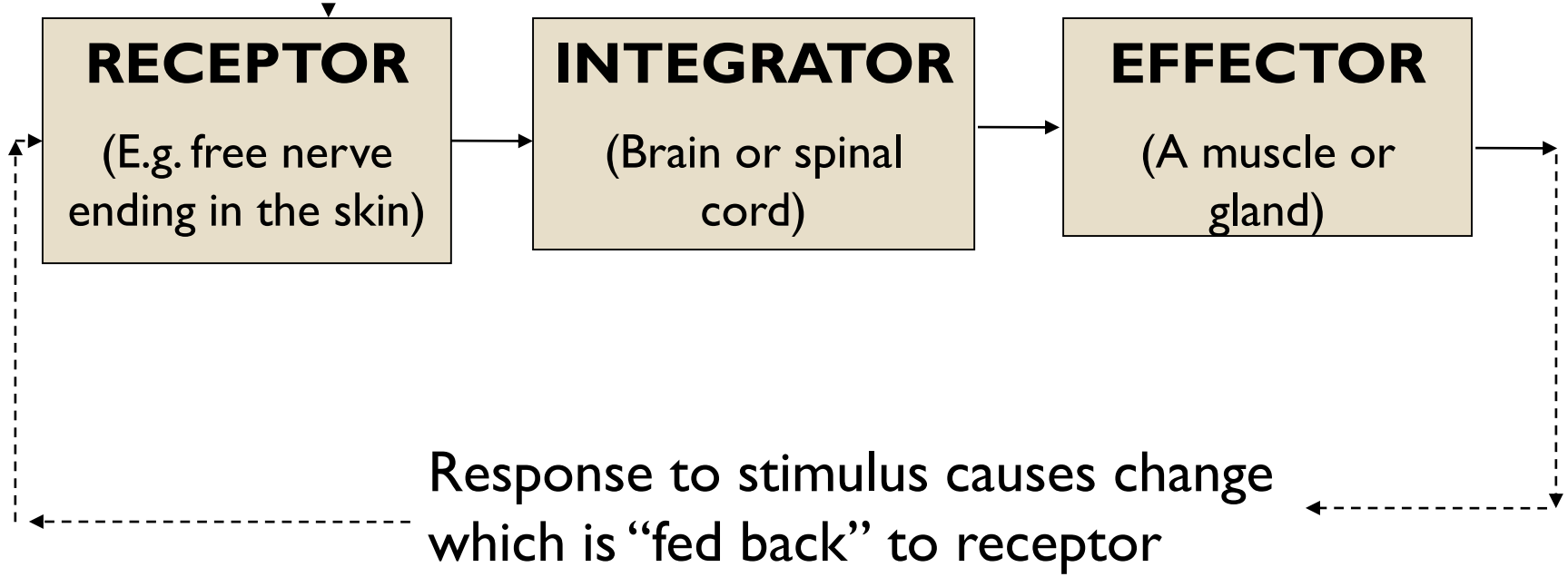
- **Effector:-** in reaction to signals from the integrators, bring about suitable response(s) e.g. Muscles and glands

APPLICATION OF THE CONTROL SYSTEM

- Every structure from the level of the cell to the system contributes in some way to keep the internal environment within limit
  - Respiratory system
  - Digestive system and related organs
  - Nervous and endocrine system
  - Cardivascular system

Three components of feedback system (loop)

Stimulus (input into system)



- Homeostasis is maintained by ***feedback mechanisms.***

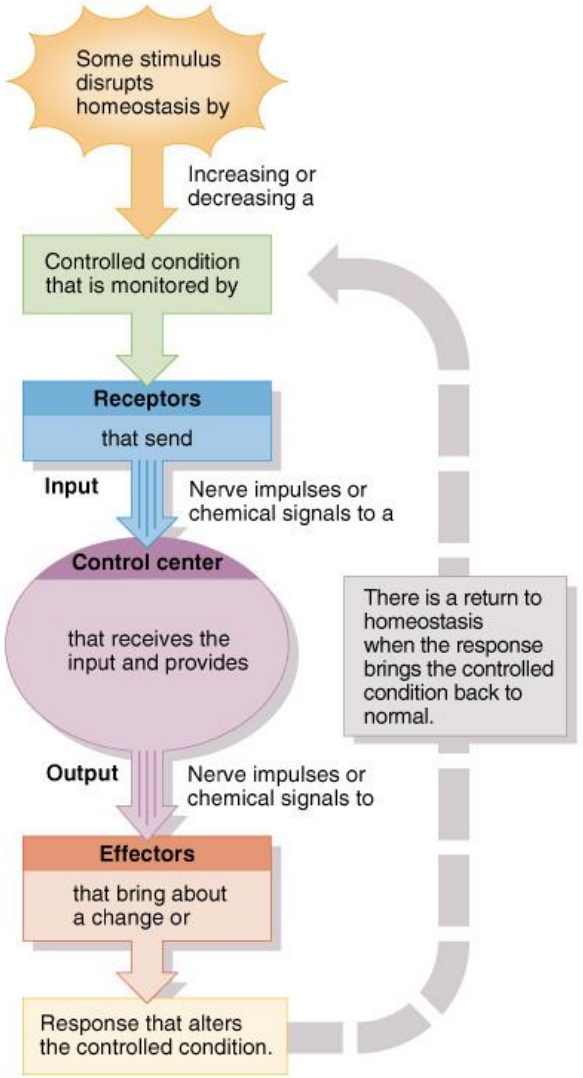
Definitions:

- A loop system in which the system responds to perturbations either in the same direction (positive feedback) or in the opposite direction (negative feedback).

- A process in which the level of one substance influences the level of another substance.

- A mechanism or a signal that tends to initiate (or accelerate) or to inhibit (or slow down) a process.

Components of Feedback Loop



- Receptor
  - monitors a controlled condition
- Control center
  - determines next action
- Effector
  - receives directions from the control center
  - produces a response that changes the controlled condition

Negative and Positive Feedback Loops

- **Negative feedback loop**
  - original stimulus reversed
  - most feedback systems in the body are negative
  - used for conditions that need frequent adjustment
  - body temperature, blood sugar levels, blood pressure

- **Positive feedback loop**
  - original stimulus intensified
  - seen during normal childbirth

- **Positive feedback :**

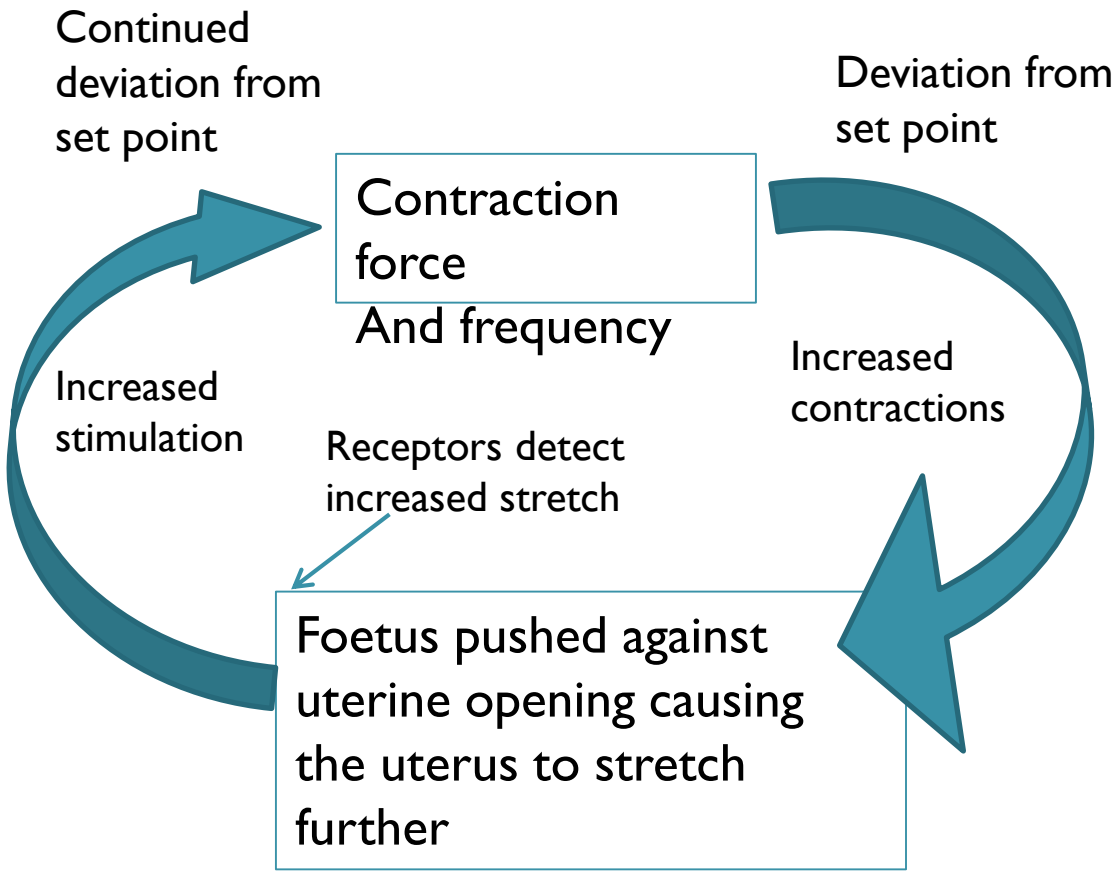
❖ A feedback in which the system responds to the perturbation in the same direction as the perturbation.

❖ feedback mechanism resulting in the amplification or growth of the output signal.

  - In this system, the original perturbation signal is amplified, and the output can grow exponentially or even hyperbolically

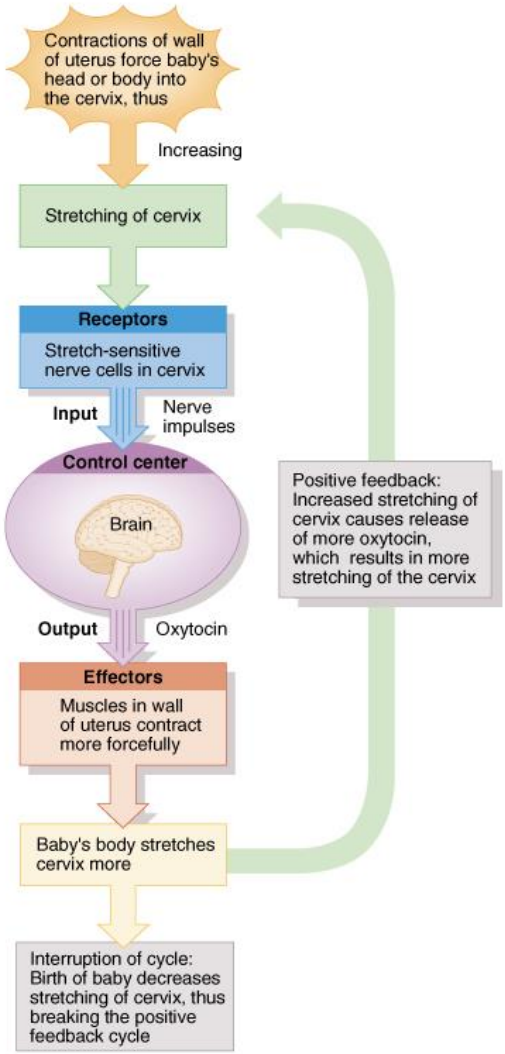
  - Positive feedback mechanisms are generally unstable

An example of positive feedback loop is the onset of contractions in childbirth. When contraction begins, the hormone oxytocin is released into the body to stimulate further contractions.



Positive feedback during childbirth

Positive Feedback during Childbirth



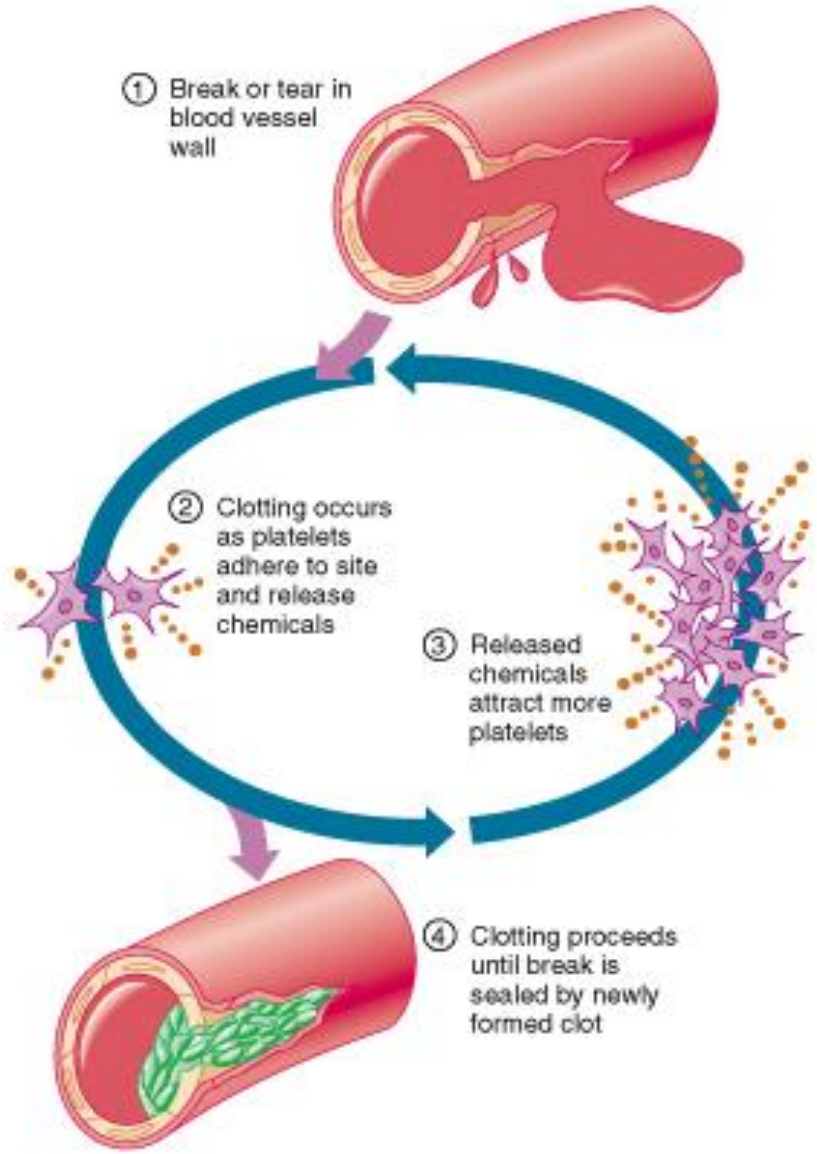
- Stretch receptors in walls of uterus send signals to the brain
- Brain releases hormone (oxytocin) into bloodstream
- Uterine smooth muscle contracts more forcefully
- More stretch, more hormone, more contraction etc.
- Cycle ends with birth of the baby & decrease in stretch

- Another example occurs in blood clotting where clotting factor activates another that cascades quickly leading to the formation of a clot.

- The ripening apple releases the volatile hormone ethylene which accelerates the ripening of unripe fruits in the vicinity

- Breastfeeding

Positive Feedback in regulation of blood clotting



- **Negative feedback:-** A feedback in which the system responds in an opposite direction to the perturbation

  - It is a self-regulatory system in which it feeds back to the input a part of a system's output so as to reverse the direction of change of the output.

  - The process reduces the output of a system in order to stabilize or re-establish internal equilibrium.

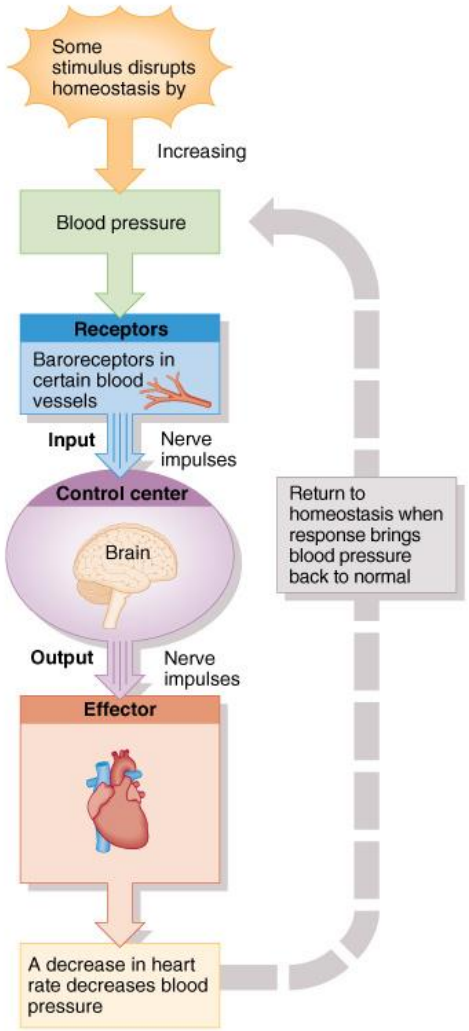
- The negative feedback leads to stability in physiological system.
  - ✓ water balance
  - ✓Glucose levels
  - ✓ blood volume
  - ✓ blood pressure
  - ✓ temperature
  - ✓ oxygen
  - ✓ carbon dioxide etc.

- In these instances, these effects are ***negative to the initiating stimulus, ie. it is in the opposite direction.***

- Most biologic processes use negative feedback to maintain homeostasis

- An example is the regulation of blood glucose levels.
- Temperature regulation
- Homeostasis of blood pressure

Homeostasis of Blood Pressure



- Pressure receptors in walls of certain arteries detect an increase in BP
  - blood Pressure = force of blood on walls of vessels
- Brain receives input and signals heart and blood vessels
- Heart rate slows and arterioles dilate (increase in diameter)
- BP returns to normal

Regulating levels of glucose in the blood

- Whiles eating, digestion introduces large amount of glucose into the body within a short time

- When the level within the blood exceeds normal, the excess is transported to the liver and stored as glycogen

- In between meals/while fasting, when glucose level drops below normal range, the liver breaks down its glycogen to add more glucose to the blood stream.

- Thus the glucose level in the blood plasma do not remain elevated immediately after a meal and does not drop too low between meals.

Regulating Body Temperature

- When the temperature of the blood exceeds 37°C, neurons in the hypothalamus detect the change
- Acting through the control of motor neurons, the hypothalamus responds
  - by promoting the dissipation of heat through sweating, dilation of blood vessels in the skin among others

- These responses tends to counter the rise in body temperature
- When body temperature falls, the hypothalamus coordinates different set of responses
  - such as shivering, and constriction of blood vessels in the skin which help to raise the temperature and correct the initial challenge.

- **TEMPERATURE HOMEOSTASIS**
- Thermal Equilibrium is when metabolic heat (Qm) is equal to heat loss (Qe +Qs)
  - Qe= Evaporative heat loss
  - Qs= Heat loss from
    - ✓ Conduction
    - ✓ Convection
    - ✓ Radiation

- Internal body temperature change has a striking effect on many physiological processes.

- For many processes, a 10°C increase in temperature will increase the rate of a process by 2 to 3-times.

❖ **Q_{10} = the change in the rate of a process caused by a 10°C change in body temperature** (defined broadly = temperature effects on a process)

ANIMALS

Heat Exposure (Ambient temp and radiation)

- Behavioural changes
- Feed intake decreases with heat to decrease heat of digestion
- Animal moves
- Decreased libido

- Physiological responses
  - Increase Qe: sweat, pant
  - Increase Qs: dust bathe, soil contact, water contact

- Physiological adaptations

Cold exposure (Ambient temp)

- Heat production
- Increase feed intake
- Movement
- Non-shivering thermogenesis
- Brown adipose tissue
- Shivering thermogenesis
- Altered hormones and energy expenditure decrease production.
- Body size is greater in colder environs
- Appendage size reduced in cold environs

WATER HOMEOSTASIS/BALANCE

- Much of this is related to temp.
- Highly efficient kidneys
- Metabolic water
- Terrestrial animals and saltwater fish face water conservation problems.
- Saltwater invertebrates (and hagfish) don't, because they are compensators.
- Freshwater animals face problems with ridding themselves of excess water (unless they adopt a compensator strategy).

Homeostatic Imbalances

- Disorder = abnormality of function

- Disease = homeostatic imbalance with distinct
  - symptoms---changes in body function felt by the patient such as nausea and
  - signs----changes in body function that can be observed by the doctor such as rash or fever

Diagnosis

- -skill of distinguishing one disease from another

Advantages of Homeostasis

- Homeostasis has a survival value because the organism can adjust to changes, for example in temperature and water availability.
  - without it, component cells will be adversely affected since they are having all their needs met by the controlled internal environment.

- Warm blooded animals are capable of living in a range of different habitats from cold polar regions to hot tropical regions because of the effectiveness of their mechanisms for temperature control.

- A constant internal environment makes it possible for cells to become more specialised and efficient in a particular task.

- Thus some cells can become organised into tissues specialised to maintain the ionic composition of the internal environment (e.g.: the kidneys), and others maintain optimum levels of O_2 and CO_2 (e.g.: the lungs).

- The body will attempt to maintain a norm, the desired level of a factor to achieve homeostasis.
- However, it can only work within tolerable limits, where extreme conditions can disable the negative feedback mechanism.
- In these instances, death can result, unless medical treatment is executed to bring about the natural occurrence of these feedback mechanisms

Possible disadvantage of homeostasis

- It requires the organism to invest effort into maintaining internal stability.
  - E.g. additional energy is required to maintain a warm body temperature in a cooler external environment. This could be a problem if food is scarce.

- Also, in some situations the complex web of homeostatic regulations and controls may break down, giving rise to illness.

- If systems, organs, tissues, and cells that are normally concerned in maintaining internal balances become damaged or diseased, the survival of the whole organism can be put at risk.

- Extreme environments……..
  - Desert region
  - Cold region
  - High altitude
  - Aquatic environment