SLE 132 – Form and Function
Homeostasis and regulation of the internal environment

DEAKIN COLLEGE
in association with
DEAKIN UNIVERSITY AUSTRALIA

Homeostasis

Maintaining a relatively stable internal environment

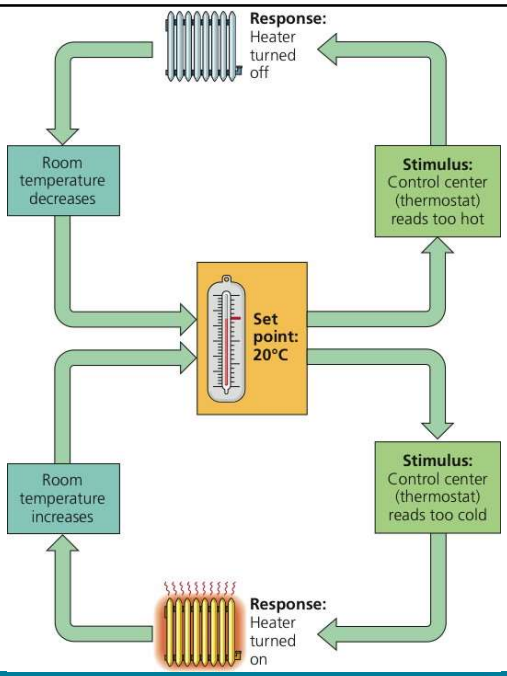
- Cells and bodies work better in stable and favourable conditions
  - Cells would die if internal conditions fluctuated dramatically
  - Enzymes would not function optimally at all times
- But is a balancing act
  - e.g. heat produced/heat lost

Regulation of internal environment

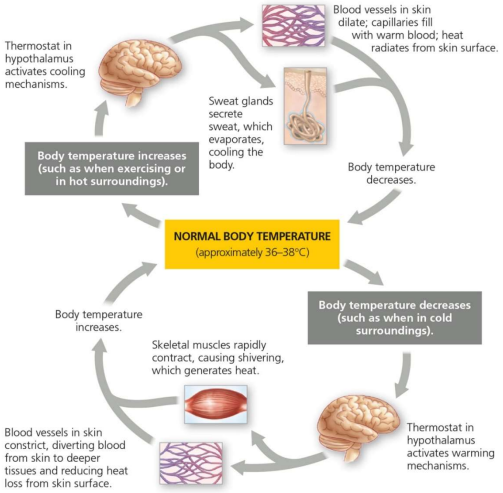
- Many animals can maintain a relatively stable internal environment, while the conditions in external environment vary widely
  - This <u>improves the efficiency</u> of various cellular processes – e.g. Enzyme function
- Process of regulation is **Homeostasis**
- Basis of Homeostasis is negative feedback system.

Negative Feedback

a change in the environment produces a response to counteract the change



Biological example of negative feedback: control of body temperature



◀ Figure 40.18 The thermostatic function of the hypothalamus in human thermoregulation.

WHAT IF? *Suppose at the end of a hard run on a hot day you find that there are no drinks left in the fridge. If, out of desperation, you dunk your head into some ice-cold water, how might the water affect the rate at which your body temperature returns to normal?*

Homeostasis – Negative Feedback

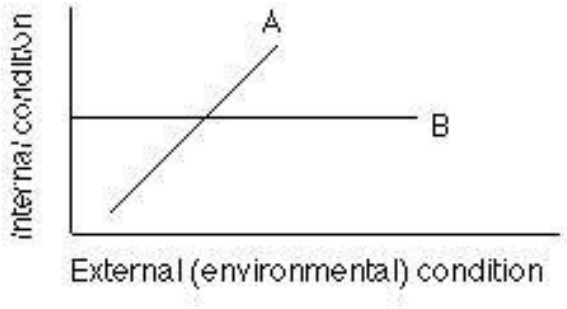
requires 3 functional components

- **Receptor** – detects change outside of normal range
- **Control Centre** – hypothalamus
  receives notification and sends signals to effector targets
- **Effector** – brings conditions back to normal

- **Positive feedback:** Amplifies stimulus in the same direction. Does not play a major role in homeostasis, but does in other systems.
  (Milk production and uterine contractions).

Animals cope with environmental fluctuations in different ways

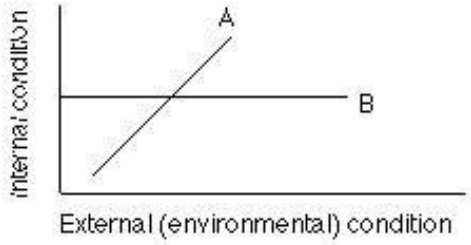
- **Regulators (B)**
  - Use mechanisms to maintain stable internal environment when external conditions fluctuate
- **Conformers (A)**
  - Allow internal environment to vary with external changes



Note: No animals are perfect regulators or conformers – most use a combination of these 2 strategies

Conformers tend to live in stable environments such as the sea

- What happens if a conformer is placed in varying conditions? – e.g. a crab is placed in varying salinities
- Crab will die at extremes, as it does not have the mechanisms to regulate



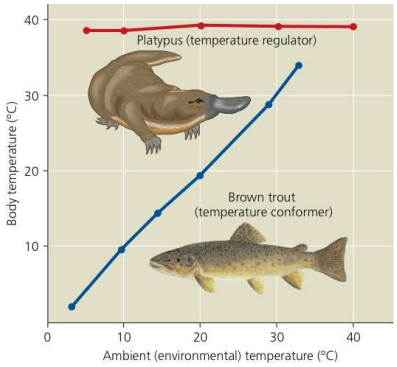
Three ways animals can regulate internal environment

- **Thermoregulation**
  - Maintaining body temperature within a tolerable range
- **Osmoregulation**
  - Regulating solute balance and the gain and loss of water
- **Excretion**
  - The removal of nitrogen – containing waste products of metabolism such as urea

Regulation of body temperature

- Cell function strongly influenced by temperature (**Enzyme function**)
- This influences animals function
  - e.g. Power and speed of muscle contraction
  - Efficiency of chemical reactions
- Different species of animals are adapted to different optimum temperatures
  - e.g. Ice fish in Antarctica/fish in tropics

Two strategies for regulating body temperature



Ectotherms

- heat is from external environment
- Low metabolic rates – generates little heat
  - Most invertebrates, fish amphibians and reptiles

Endotherms

- High metabolic rates – enough heat to keep body temperature higher than external temperature
- Mammals, birds, some fish, a few reptiles and many insects
- Requires a lot of energy – especially in cold environments (need more food)

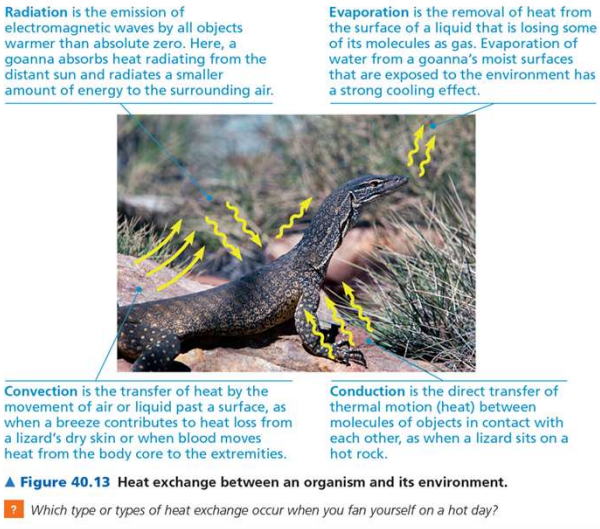
Balancing heat loss and gain

Radiation – emission of electromagnetic waves by all objects warmer than absolute zero

Evaporation – removal of heat from the surface of a liquid that is losing some of its molecules as gas

Convection – transfer of heat by the movement of air or liquid past a surface

Conduction – direct transfer of heat between molecules of objects in contact with each other



▲ **Figure 40.13** **Heat exchange between an organism and its environment.**

? *Which type or types of heat exchange occur when you fan yourself on a hot day?*

Both ectotherms and endotherms have adaptations for thermoregulation

Modifying rate of heat gain or loss

1. **Cooling via evaporative water loss**
2. **Behavioural Responses**
3. **Adjust heat exchange (loss or gain) with the environment**
4. **Change rate of metabolic heat production**

Spend 5 minutes coming up with a specific example for each of the above.

Osmoregulation

- Is the regulation of body fluid chemistry, through regulation of solute composition and movement of water (osmosis)
- Entails the removal of metabolic wastes
- Goal is to maintain constant cellular composition by managing the composition of the fluid bathing cells (haemolymph or interstitial fluid)

Have you done the before class activity?

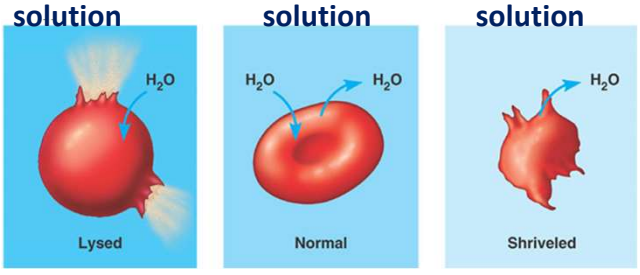
What is osmosis?

The movement of water across a selectively permeable membrane. Water moves from a hypo-osmotic region, to a hyper-osmotic region.

Animal cells cannot survive in environments where they take up or lose water

What happens when you put a cell into a(n):

Hypo-osmotic solution | **Iso-osmotic solution** | **Hyper-osmotic solution**



- Hence single celled animals live in **iso-osmotic** solutions
- Cells within multicellular animals need to be bathed in an iso-osmotic solution (animal cells must be surrounded by fluid osmotically balanced with cytoplasm)

Animals need to maintain an internal water balance

An iso-osmotic environment is the most suitable and easiest environment to inhabit.

Other options

- Avoid environments that are not iso-osmotic (osmo-conformers)
- Regulate a constant internal environment (osmo-regulators)
  - Need for special adaptations to counteract the uptake or loss of water and salts
- One of the biggest problems faced by animals is that excretion of wastes requires water

Osmoconformers

- **Many marine animals, especially invertebrates**.
- Aquatic animals whose body fluids have same solute concentration as their environment
- No net gain or loss of water
  - Equal amounts of water move in and out of the animal

Osmoregulators

- Animals whose body fluids do not have the same solute concentration as their environment
- **This is the case for:**
  - All freshwater animals
  - Many marine animals
  - All terrestrial animals
- These animals have to expend energy to control (or regulate) water loss and gain

Marine Animals

- Many marine vertebrates and some marine invertebrates (not the shrimp) are **osmoregulators**
- For most of these animals, seawater is a strongly dehydrating environment
  - i.e. they lose water to the hyperosmotic sea and must therefore balance this loss by taking in water

Freshwater Animals

- Have the opposite problem to marine animals
- They gain water by osmosis and lose salts by diffusion
- Many freshwater animals solve the problem by **drinking nothing** and secreting large amounts of dilute urine
- And **replenishing salts** (lost by diffusion and in urine) by eating. Some freshwater fish (cod) can take up salts across the gills

Osmoregulator:
Saltwater fish Freshwater fish

- Which is hypo-osmotic compared to it's environment?
- Which is hyper-osmotic?

- What problem does each face?
  ie. lose or gain water?

- What mechanism do they use to osmoregulate?

Terrestrial animals also need to osmoregulate

Problem: loss of water to environment (dehydration)

- **Gain water by**
  - Drinking
  - Food
  - Metabolic water (by-product of cell respiration)
- **Lose water by**
  - Respiration
  - Evaporation
  - Waste removal

Terrestrial animals also need to osmoregulate

Solutions:

- Protective barriers (skin)
- Behaviours
- Efficient excretory organs to reduce water lost in excretion (some animals are so efficient they never need to drink!)

Animals must dispose of nitrogenous waste

- Disposing of nitrogenous wastes is **as important to homeostasis as water and solute balance**
- Amino groups ($-NH_3$) are breakdown products from the metabolism of proteins and nucleic acids
- Simplest compound formed is Ammonia (NH_3)
  - Ammonia is toxic
    - Raises pH of body fluids
    - Interferes with membrane transport

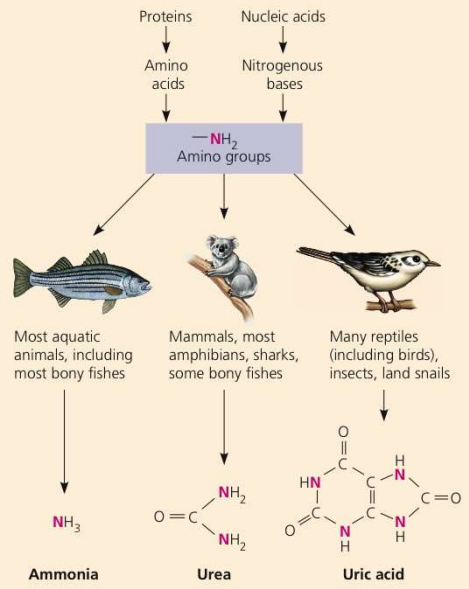
Animals must dispose of nitrogenous waste

- Ammonia can't be stored and must be excreted immediately
- Ammonia is highly soluble in water, so rapidly diffuses out in dilute form with lots of water
- (can use a lot of water to 'flush' it out)
- This is not suitable for animals with less water available

Terrestrial animals convert amino groups to less toxic compounds

- **Urea** - Mammals, adult amphibians
  - Can be stored
  - Is soluble in water and needs water for excretion

- **Uric Acid** - Birds, reptiles, insects
  - Can be stored
  - Is more complex and requires more energy to produce it
  - Virtually insoluble in water, so its needs very little or no water for its excretion



Quick Question

Consider an ectotherm and an endotherm of equal body size/ The ectotherm is more likely to survive an extended period of food deprivation than the endotherm because?

a) The ectotherm is sustained by a higher basal metabolic rate
b) The ectotherm will expend less energy/kg body weight than the endotherm
c) The ectotherm will invest little to no energy in temperature regulation
d) Both b and c are correct

Quick Question

The advantage of excreting wastes as urea rather than ammonia is?

a) Urea can be exchanged for sodium
b) Urea is less toxic than ammonia
c) Urea does not affect the osmolar gradient
d) Less nitrogen is removed from the body

Quick Question

Which if the following nitrogenous wastes is excreted with minimal water?

a) Ammonia
b) urea
c) Uric acid
d) Amino acid
e) Nitrogen gas