Unit I – Problem 6.7 – Physiology: Body Temperature Regulation and Fever

- **Core temperature vs skin temperature:**
  - **Core temperature:** temperature of deep tissues which is relatively constant (± 1 F under normal conditions).
  - **Skin temperature:** it differs widely because it depends on the temperature of the environment.

- **Normal body temperature:**
  - Normally = 37 C. Notice that extremities are generally cooler than the rest of the body.
  - Rectal temperature represents the core temperature of the body and it is not affected by changes in environment temperature.
  - Morning oral temperature = 36.7 C (± 0.2 C). Oral temperature is (0.5 C) less than rectal temperature and it is affected by many factors:
    - Ingestion of hot or cold fluids.
    - Gum chewing.
    - Smoking.
    - Mouth breathing.
  - The temperature of the scrotum = 32 C (less than normal body temperature because this is more suitable for spermatogenesis: production of sperms).
  - In females, basal temperature rises at time of ovulation (usually day 14 of the menstrual cycle).
  - **Normal body temperature range:**

<table>
<thead>
<tr>
<th>°F</th>
<th>°C</th>
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<tbody>
<tr>
<td>74</td>
<td>24</td>
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<td>76</td>
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<td>110</td>
<td>42</td>
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<td>114</td>
<td>44</td>
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- Upper limit of survival?
- Heatstroke
- Brain lesions
- Fever therapy
- Febrile disease and hard exercise
- Usual range of normal
- Lower limit of survival?
- Rate of heat production by a normal 70 kg person can vary from 75-80 kcal/hour when sitting to more than 1400 kcal/hour at maximum rates of exercise.

- **Thermoregulation:**
  - The body has well developed mechanisms for balancing heat production with heat loss.

<table>
<thead>
<tr>
<th>Heat production</th>
<th>Heat loss</th>
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<tbody>
<tr>
<td>Muscular activity</td>
<td>Radiation</td>
</tr>
<tr>
<td>Basic metabolic processes</td>
<td>Conduction and convection</td>
</tr>
<tr>
<td>Food intake</td>
<td>Evaporation of sweat</td>
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<tr>
<td></td>
<td>Respiration</td>
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<td>With urine and feces</td>
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</table>
• Physics of heat loss from the body:

From the graph below you will notice that core temperature remains stable despite wide variations in atmospheric temperature.

• How is heat lost from the body when the environmental temperature is greater than the body temperature?
  ✓ When environmental temperature rises, there will be vasodilation which will increase heat conductance through the skin.
  ✓ Sweating:
    √ Sweat glands are innervated by acetylcholine-secreting sympathetic nerves.
    √ Rate of sweat production varies from 0 to 1.5 L/h
    √ Notice that 1L of water evaporated from the surface of the skin can lead to heat loss of 580 kcal.
    √ Sweat gland:
      ➢ Primary secretion: mainly protein-free filtrate.
      ➢ In the ducts there will be absorption of sodium and chloride ions from the primary secretion.

<table>
<thead>
<tr>
<th>Temperature decreasing mechanisms</th>
<th>Temperature increasing mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vasodilation: transfers heat to the skin</td>
<td>Vasoconstriction</td>
</tr>
<tr>
<td>Sweating: evaporative heat loss</td>
<td>Piloerection: usually not important in humans</td>
</tr>
<tr>
<td>Decreased heat production: shivering and chemical thermogenesis are inhibited</td>
<td>Increased heat production: shivering; sympathetic excitation of heat production; thyroxine secretion</td>
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</tbody>
</table>
**How is body temperature detected?**
- **Hypothalamus temperature control center:**
  - Preoptic area of anterior hypothalamus.
  - Heat sensitive and cold sensitive neurons.
- **Skin and deep body temperature receptors:**
  - Mainly detecting cool temperatures.
  - Function to prevent hypothermia.
- **Role of posterior hypothalamus:**
  - Receives input from anterior hypothalamus and peripheral temperature receptors to elicit mainly heat producing and heat conserving reactions.

**Response to cold environment:**
- Increase in sympathetic activity:
  - Stimulates chemical thermogenesis (NE and E → ↑metabolic rate).
  - Initiates piloerection.
  - Shivering thermogenesis.
- Notice that long-term cold exposure stimulates hypothalamus to produce more Thyroid Releasing Hormone (TRH).

**Response to hot environment:**
- Vasodilation of cutaneous circulation.
- Sweating: regulates sensible evaporative heat loss; critical for cooling in environment hotter than body.
- Decreased heat production.

- **Fever: resetting the set-point $T^0$**
  - Pyrogens (bacteria and degenerating tissues) can directly reset set-point.
  - Pyrogens can indirectly reset set-point:
    - Interleukin-1 (IL-1) released from phagocytes following phagocytosis of blood-borne pyrogens.
    - (IL-1) raises set-point by increasing prostaglandin production (mainly E₂).

**Pathogenesis of fever:**

- Fever-producing stimuli:
  - Gram-negative bacilli
  - Viruses
  - Fungi
  - Endotoxins: Antigen/antibody reactions

- Circulation
  - Macrophage
  - T lymphocyte
  - Immune response: activation of lymphocytes, neutrophils, microphages
  - Acute-phase response
  - Cytokines
  - Liver and metabolic responses
  - Immune response: reticuloendothelial cell systems

- Blood-brain barrier
  - Brain (OVLT: endothelial cells)
  - Release of prostaglandin (PGE₂)
  - Increases $T^0$
  - Fever
- **Time course of fever:**

- **Heat stroke:**
  - It occurs when body temperature rises above 106-108 F:
    - Malfunction of preoptic temperature control center: sweating ceases.
    - Rising body temperature increases metabolism which generates more heat.
  - Symptoms include:
    - High body temperature: ≥ 40°C
    - Altered mental state or behavior.
    - Alteration in sweating:
      - *Heat stroke brought on by hot weather*: dry skin.
      - *Heat stroke brought on by strenuous exercise*: moist skin.
    - Nausea and vomiting.
    - Flushed skin.
    - Rapid breathing.
    - Racing heart rate.
    - Headache.

- **Heat exhaustion:**
  - Due to circulatory problems:
    - Excessive loss of salt and water due to severe sweating.
    - Heat cramps.
    - Vasodilation.
    - Venous return compromised.
    - Circulatory collapse.
    - Notice that body temperature may not be very high.
  - It is common in elderly, athletes and soldiers when doing heavy exercise in hot environment, persons taking drugs that inhibit sweating and/or vasodilation such as atropine.

- **Acclimatization to heat:**
  - Increased tolerance to hot and humid environment occurs in 5-10 weeks.
  - Physiological changes:
    - ↑ in the maximal rate of sweating.
    - ↓ loss of salt in the sweat and urine.
    - ↑ plasma volume.