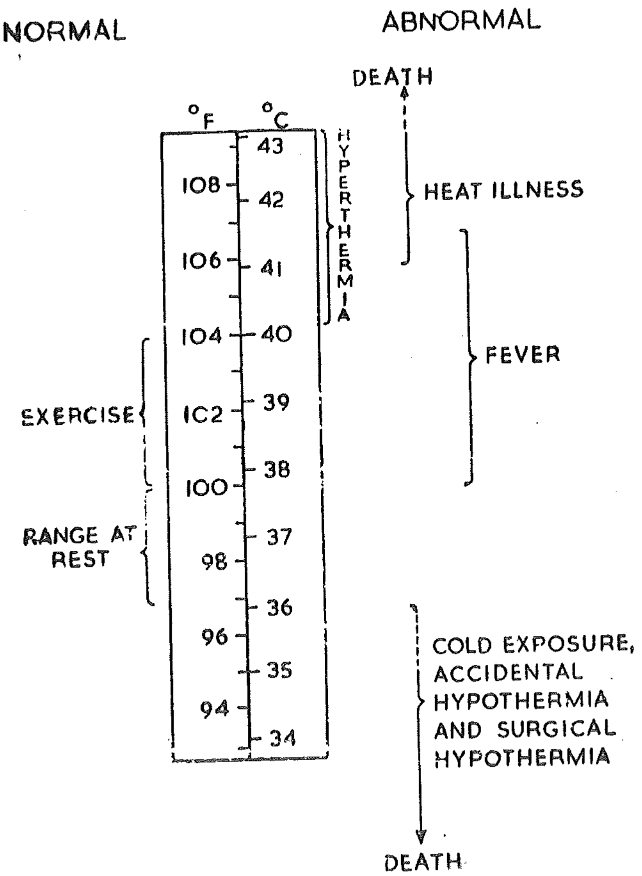
Introduction.

It is sometimes stated in Physiological text books that the skin is surrounded by a layer of still air. However, because the body temperature is normally higher than that of the surroundings, the air next to it becomes warmed and rises due to its buoyancy. The body is thus surrounded by a layer of rising heated air, the natural convection boundary layer.

In still air conditions, the natural convection boundary layer forms the inter facial region between the skin surface and its surroundings. This region constitutes the human micro-environment. Within it rapid adjustments of temperature and of humidity take place, and it also plays a role in transporting small particles, such as dust, pollens, skin scales and bacteria. The layer becomes modified by any relative movement between the body and the surroundings, and, for instance by the presence of clothing. A general account of the layer and its visualisation in a schlieren system is given in ref. 1. It should also be recognised that a similar micro-environment exists when a body is immersed in a fluid such as water. In the present lecture, only the air case is dealt with.

Body Temperature.

In a healthy subject, for all practical purposes, the body surface temperature has a mean value of 33°C at rest. This temperature may fluctuate as much as ± 4°C depending on the need to eliminate or conserve body heat. The body core temperature has a value of around 37°C and the range of temperatures in various activities is given in the following table.



The range of human body temperature (oral) in health and illness.

Local areas where the surface temperature may differ are the extremities, where the surface area per unit volume is large, and here the temperature will be lower. The range of variation between healthy subjects is surprisingly small. Physical conditions such as fever or heat stroke are instances where the surface temperature of the body can be raised as high as 40°C (hyperthermia). Cold exposure - hypothermia - causes the temperature to fall.

External Temperatures.

These may vary from, say, -60°C to + 40°C but taking 15°C as a typical figure in temperate climates there is thus normally an 18°C temperature drop between the body and its surroundings.

The Natural Convection Boundary Layer.

The boundary layer flow may be either laminar or turbulent, depending on the ratio of bouyancy forces to viscous forces in the layer.
This ratio is expressed in terms of the Grashof Number

$$G_r = \frac{g x^3}{\nu^2} \frac{T_\omega - T_\infty}{T_\infty}$$

where
x = vertical height
ν = kinematic viscosity
T_ω = skin temperature
T_∞ = ambient temperature
g = gravitational acceleration

If the Grashof number exceeds 10^{10} (Cheesewright, ref. 14 and ref 15) the buoyancy forces predominate, and the layer becomes turbulent. There is a transition region from $2 \times 10^9 > G_r > 10^{10}$

If we take the case of a naked standing human subject with an ambient temperature of 15°C, the flow is laminar up to the centre of the abdomen, there is a transition region of about 50 cms, and the flow is turbulent over the upper part of the thorax and the head.

Since the temperature difference appears in the Grashof number as the term $\frac{T_\omega - T_\infty}{T_\infty}$ variations of the temperature difference will modify this general picture, as will inclination of the surface being considered (Ref 7)

The thickness of the layer, and the velocity and temperature distributions depend also on the ratios of transport of momentum and of heat in the layer; that is to say on the ratio of the viscosity ν to the thermal diffusivity α . This ratio is known as the Prandtl number.

$$P_r = \nu/\alpha = \mu C_p/k$$

where μ = viscosity
C_p = specific heat
k = thermal conductivity

For dry air its value is 0.73 and for saturated water vapour it is 0.96.