

# Homeostasis

## Part 1: anatomy and physiology

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This article, the first in a series of four, looks at the anatomy and physiology of homeostasis. Homeostasis comprises the dynamic processes that enable optimum conditions to be maintained for cells, in spite of continual changes taking place internally and externally (Clancy and McVicar, 1995).

All the systems of the human body are involved, with particular contributions by the endocrine, nervous, respiratory and renal systems. Whenever an imbalance occurs, regulatory systems become active to restore optimum conditions, usually by a process known as negative feedback in which a deviation from the normal level is detected and initiates changes that bring the level back to where it should be (Clancy and McVicar, 1995). These systems have to endure for survival and adapt to modifications of the environment so must therefore evolve.

### Anatomy and physiology

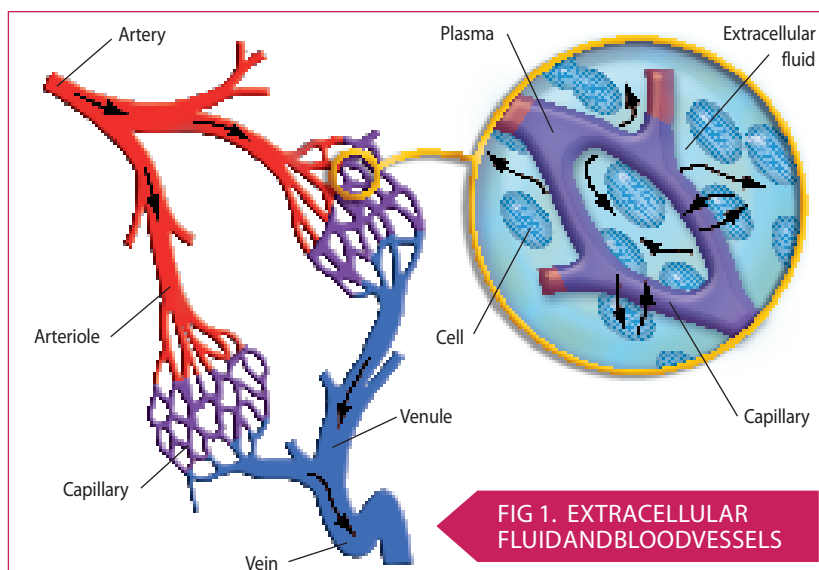
Many factors affect the suitability of body fluids to sustain life. These will be explored later in this series. They include:

- Oxygen ( $O_2$ ) and carbon dioxide ( $CO_2$ ) concentrations;
- The pH of the internal environment;
- Concentrations of nutrients and waste products;
- Concentration of salt and other electrolytes (osmoregulation);
- Volume and pressure of extracellular fluid;
- Body temperature;
- Blood glucose level.

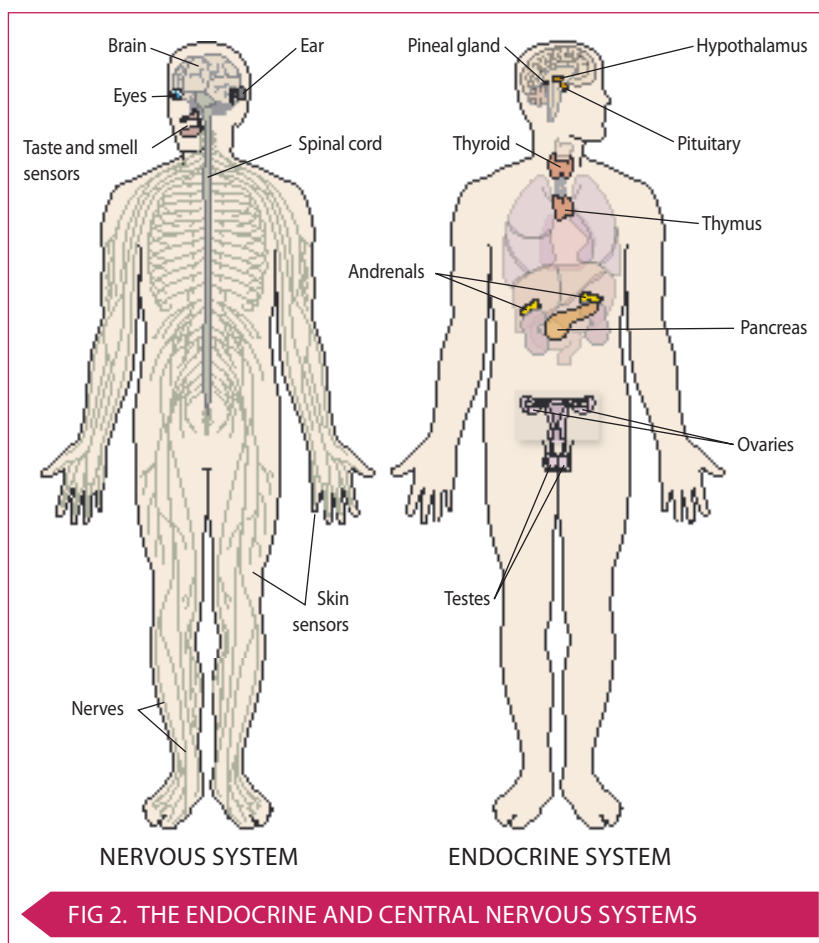
As these properties affect the chemical reactions that sustain life, there are built-in physiological mechanisms to maintain them at desirable levels. The body needs homeostasis to maintain stability and survive by ensuring that the internal environment remains relatively constant (Tortora and Anagnostakos, 2003).

To enable cells to survive, the composition of the intracellular and extracellular fluids must be accurately maintained at all times. Intracellular fluid accounts for two-thirds of total water content (Tortora and Anagnostakos, 2003). Extracellular fluid includes gases, nutrients, plasma (in blood vessels) and ions, all of which are necessary for maintaining life (Tortora and Anagnostakos, 2003) (Fig 1).

Extracellular fluid circulates constantly within



**FIG 1. EXTRACELLULAR FLUID AND BLOOD VESSELS**



**FIG 2. THE ENDOCRINE AND CENTRAL NERVOUS SYSTEMS**

the blood and lymphatic system and is known as 'the body's internal environment' (Tortora and Anagnostakos, 2003).

The body is said to be in homeostasis when its internal environment contains:

- Optimum levels of gases, ions, water and nutrients;
- Is at optimal temperature;
- Has optimal pressure for the health of cells.

A disturbance in these optimum conditions causes failure of the organs and may lead to death (Tortora and Anagnostakos, 2003).

### Homeostatic control

The endocrine and central nervous systems are the major control systems for regulating homeostasis (Tortora and Anagnostakos, 2003) (Fig 2). The endocrine system consists of a series of glands that secrete chemical regulators (hormones). The nervous system can detect deviation from the body's normal equilibrium (state of homeostasis) and sends messages to the affected organ to counteract this disturbance. Over a relatively short time it restores the required balance. Both systems act mostly automatically but there is some voluntary control over the nervous system (Sherwood, 1997).

The control and maintenance of blood sugar levels is an example of homeostatic regulation by the endocrine system. Blood sugar is maintained by two hormones secreted by the pancreas: insulin and glucagon. Blood sugar rises after digestion of food. In response, pancreas cells are stimulated to secrete insulin, which enables sugar uptake by cells and the storage of sugar in the liver and muscles. In effect, insulin decreases blood sugar levels to normal (Tortora and Anagnostakos, 2003).

The respiratory system provides an example of homeostatic regulation by the nervous system. In normal breathing there is a state of homeostasis. During exercise the respiratory system must work faster to keep the  $O_2$  in the extracellular fluid and in the cells within normal limits, preventing excessive build-up of  $CO_2$  and disturbance to the blood pH through the accumulation of acid (Tortora and Anagnostakos, 2003). Because muscles require more  $O_2$  during exercise, more  $CO_2$  is released and therefore also needs to be excreted (Tortora and Anagnostakos, 2003).

These chemical changes are detected in certain nerve cells, which send this message to the cardio-respiratory centre in the medulla oblongata in the base of the brain (Docherty, 2002). The brain sends a message to the heart to increase its pumping action (heart rate) to take on more  $O_2$  and enable the blood to give up excess  $CO_2$ . Respiratory muscles also receive instructions from the brain to contract faster, enabling a rise in both  $O_2$  delivery and  $CO_2$  exhalation.

### Negative feedback

Homeostasis is constantly disturbed by external factors, which can be described as a form of stress on the internal environment (Tortora and Anagnostakos, 2003). These stresses can be:

- Internal: occurring within the body, for example in pain, or as a result of high or low blood pressure;
- External: occurring outside the body, for example as a result of heat, cold or loud noises.

Since these stresses affect the chemical reactions sustaining life, there are built-in physiological mechanisms to maintain or return them to desirable levels.

Each organ or structure has its own intrinsic way of keeping the internal environment within normal limits. When homeostasis is altered there are two possible responses:

- In negative feedback the system responds to reverse the direction of change. As this tends to keep things constant, it allows the maintenance of homeostasis. For example, if there is a fall in calcium in the blood, the parathyroid glands sense the decrease and secrete more parathyroid hormone, thereby increasing calcium release from the bones;
- Positive feedback increases the variable in the same direction, a destabilising effect that does not result in homeostasis. Positive feedback is used when rapid change is needed. For example in childbirth the hormone oxytocin is produced to stimulate and enhance labour contractions (Bodyguide, 2005).

### Components of homeostasis

A system requires three components for homeostasis:

- A receptor;
- A control centre;
- An effector.

These components do specific jobs that allow regulation of the internal environment.

A receptor detects external changes that could influence the internal environment. For example, the following are involved in the regulation of blood pressure:

- Receptors are in the baroreceptor system;
- The control centre is the medulla oblongata;
- The effector is the cardiovascular system.

When there is an increase in heart rate more blood is pumped into the arteries resulting in an increase in blood pressure (Docherty, 2005). This is detected by the baroreceptors, which are located in the walls of certain arteries.

These receptors send impulses to the control centre (the medulla oblongata), which interprets the message and sends impulses to the effectors (the cardiovascular system). These slow the pulse, decreasing blood pressure (Tortora and Anagnostakos, 2003). ■

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