Introduction to Horse Biology

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Preface

Study of the horse, whether at college, university or through the British Horse Society (BHS) system is becomingly increasingly popular as students search for a career in the equine sector. Equine biology is a vital subject for students wishing to study the horse and how it works, and a fundamental knowledge of this subject is essential.

Introduction to Horse Biology supplies the information required by all students of equine subjects, particularly those without a standard qualification in biology. It includes information on cells and tissues and how they function, basic microbiology and genetics. The systems of the horse are also covered extensively, with many illustrations to aid understanding. Summary points are included at the end of each chapter.

This book will be invaluable to all students of equine subjects, including First Diploma, National Diploma, National Certificate, Higher National Diploma and Advanced National Certificate, and all students studying for BHS or other equine-related examinations. It provides a good basis for students of foundation degrees without a science background, and it is ideal for serious horse owners who search for a better understanding of horses and how they function.

Zoe Davies
2004

Dedication

This book is dedicated to my husband, Ian, and daughters, Sophie and Katie, who have provided me with the time and space required to write this book and offered complete support at all times!

1 The Living Horse – Some Basic Principles

INTRODUCTION

To understand the way the horse works, it is important to be aware of the complex systems involved. The aim of this book is to introduce both students and horse owners to the basic structure of the horse as an animal in order that they may gain knowledge and appreciation of its capabilities and limitations. To appreciate the horse's structure and function, it is helpful to have a basic knowledge of the evolution of horses (Figure 1.1).

EVOLUTION

Most religious ideas are centred on a creator of all life. However, scientific evidence, such as the presence of fossils, tells a very different story.

Darwin's Theory of Evolution

In the 1830s, Charles Darwin (1809–1882), a naturalist from Great Britain, sailed in a ship called the Beagle, to the Galapagos Islands off the coast of South America. Here he made many observations about the animals and plants he found on the Islands, and from these he produced his Theory of Evolution.

His observations included the fact that more offspring are produced than could possibly survive, but the numbers of populations still remained fairly constant. Also, all organisms within a species showed variation, and some variations are inherited (see Chapter 14, pp. 173–82). Darwin concluded from his observations that, because more offspring were produced than survived, there must be a struggle for survival of the individual and therefore the species. The fittest and strongest of the offspring survived, and the variations, or traits, which

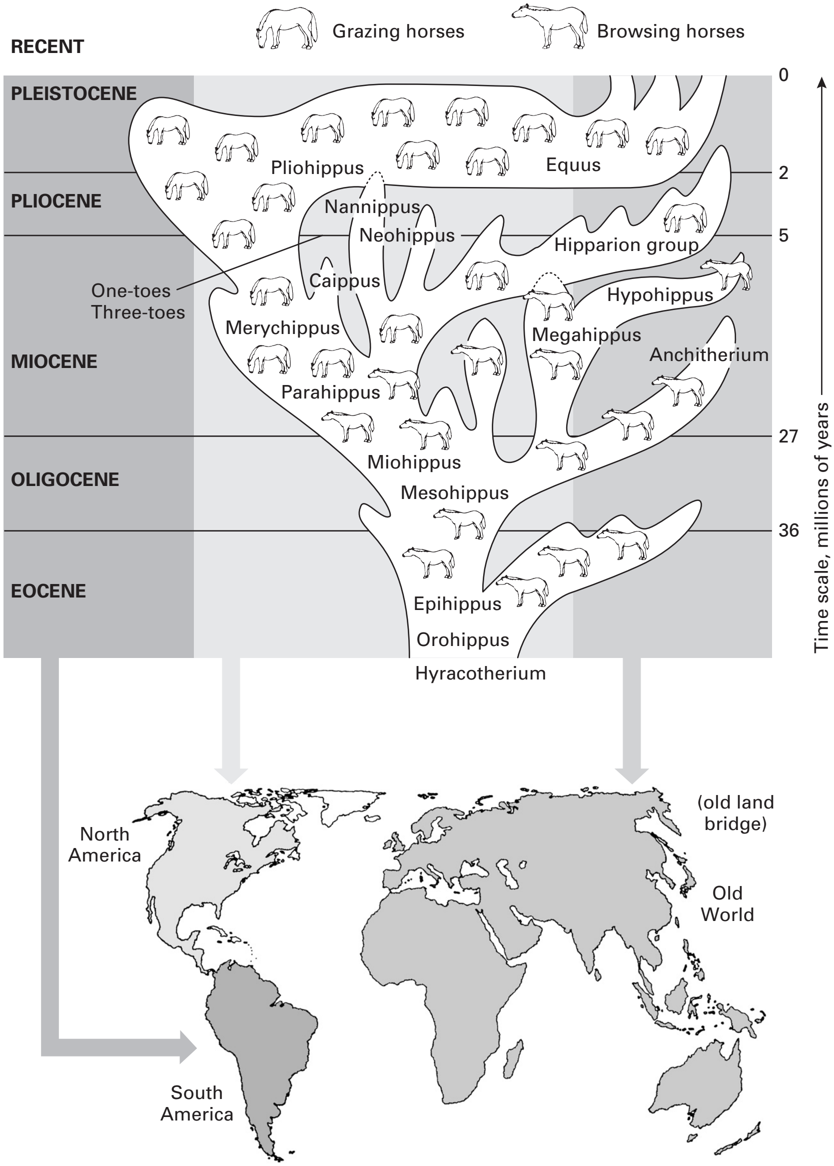

Figure 1.1 Evolution of the horse.

made them fitter and stronger were passed on in turn to *their* offspring. This process is known as *natural selection*, and it is the basis for the evolution of all species.

Natural Selection

A *species* is a group of similar organisms that breed together to produce offspring that are fertile. All horses belong to one species, *Equus caballus*, and its members share certain biological characteristics. Within a species, individuals may differ. This difference may be small or it may be big, such as the difference in height between a Shire and a Shetland, and the differences (or *variations*) may or may not be advantageous to survival.

If the environment changes over time, only the individual animals that can adapt to the new conditions will survive. These will then breed and pass on their advantageous genes to their offspring. In addition, environmental conditions, such as the number of predators, quantity of food available and occurrence of disease will also reduce the number of surviving offspring, and it will be those with advantageous variations, such as speed and immunity, that will survive. This is how natural selection works, and it is nature that 'selects' which animals survive.

Fossils

These are the remains of organisms that have died. The hard parts of the body, the skeleton for example, forms into rock and the minerals slowly infiltrate the softer parts of the body. Fossil formation takes place where there is no oxygen and it is dry and cold so that the animal does not decay but is preserved. Fossils provide great evidence for evolution. The evolution of horses is clearly shown by fossils, showing the changes in size, feet and teeth caused by changes in the environment over the years. Natural selection has resulted in the modern horse.

EVOLUTION OF HORSES

Horses may be traced back to the Eocene period, 50–60 million years ago, to a small fox-like animal known as *Hyracotherium* (also known as *Eohippus*, or 'dawn horse'). Hyracotherium was a browsing herbivore, which lived in what were then the tropical forests of North America. It is estimated to have weighed approximately 12 pounds and was 14 inches at the shoulder. Hyracotherium had four toes on the front feet and three toes on the hind feet. These were padded, similar to those of a dog. These toes and pads are now the ergots and splint bones found on the modern horse's limb.

Approximately 38 million years ago, in the Oligocene period, Hyracotherium had evolved through natural selection into *Mesohippus* then *Miohippus*, and was similar in size to a German Shepherd Dog. Due to changes in the environment, those individuals whose teeth had adapted, allowing them to browse a wider variety of plants, survived. Their front feet were now three-toed and padded, but most weight was carried on the middle toe.

In the Miocene period, approximately 27 million years ago, the defining moment in the evolution of the horse occurred. The horse's ancestors, to survive, had to move away from the tropical, swampy forests onto the plains, adapting to the new environment in a number of ways. Changes in the genetic make-up caused the head to become bigger, in order to house the longer grinding teeth, the neck to become longer, allowing the animal to reach down and graze and the position of the eyes altered to allow the animal to see the horizon whilst grazing. The limbs became longer, allowing the animal to travel at increased speeds to escape predators. These ancestors of the modern horse, known as *Parahippus* and *Merychippus*, stood most firmly on a single middle toe with side toes that were semi-functional. These animals were approximately 42 inches high (10.2 hh).

Pliohippus evolved during the Pliocene period, approximately five million years ago. The side toes were now the splint bones on either side of the cannon bones. This small slightly-built ancestor of the horse was probably the earliest prototype for *Equus caballus* (modern horse).

Equus caballus evolved during the Pleistocene period, approximately two million years ago. These animals had become well adapted to life on the open plains and were capable of great speed, having long lower limbs with an absence of muscle but a highly-muscled upper body. The foot pad of earlier ancestors is now the frog of modern horses.

Horses and other members of the family Equidae developed important social networks allowing them to live more safely in herds. These one-toed horses belonged to the genus *Equus* and these were the most recent ancestors of the horse. Figure 1.2 shows the changes to the forelimb through evolution.

Equus spread from North America to Asia, but as the glaciers retreated, approximately 10,000 years ago, land bridges between Asia and Alaska disappeared. Following this, the horse became extinct in North America, for reasons which remain unclear.

Breeds and types

Horses were domesticated at different times and places throughout the world. This has led to great variation in breeds and type, and there are now over two hundred breeds worldwide.

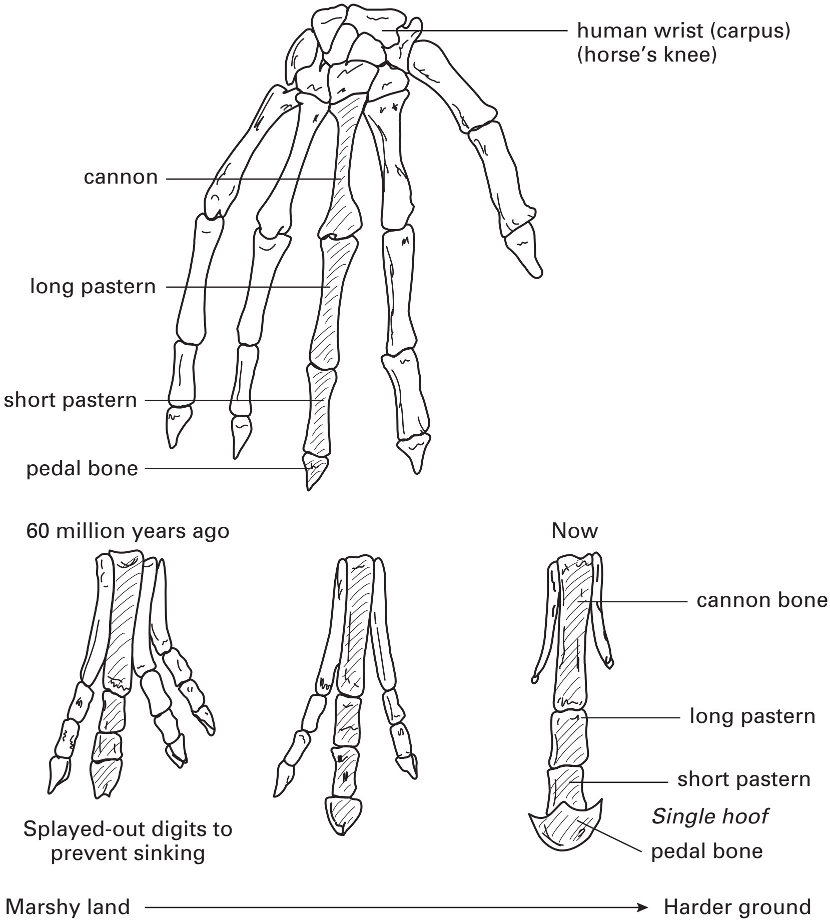

Figure 1.2 Changes in the forelimb through evolution.

Modern horses and ponies can have their origins traced back to four basic types:

- Hotbloods – Thoroughbreds and Arabs
- Warmbloods – carriage and sports horses
- Coldbloods – heavy draught horses
- Ponies – deeper bodies and shorter legs

These types do not relate in any way to body temperature, but to temperament and speed.

BEHAVIOUR OF THE MODERN DAY HORSE

The horse does not have the same level of intelligence as humans. In fact, the horse's brain is small relative to its overall size (see Chapter 10,

Figure 1.3 Herd of horses grazing.

p. 120), and its approach to life is based upon instincts that have evolved over many years to protect it in the wild, rather than upon thought. In the wild, the horse relied upon its highly-developed senses and a physical ability to move quickly away from the threat of attack from predators. The fight or flight response to danger seems to be highly developed in horses today, and they have the ability to move sharply and quickly away from a source of danger.

The modern-day horse retains most of the primitive instincts of its ancestors. Horses are strongly motivated to search for food and the companionship of other horses (Figure 1.3), particularly those familiar to it. This behaviour is often seen in small groups of horses or ponies in a field. When one of a close group or pair is taken away, then those left behind will often run about, whinnying frequently.

Another aspect of equine evolution that affects the horse's behaviour is the need to feed frequently. Wild horses spend most of their time grazing, eating small amounts of herbage little and often. This is known as trickle feeding and the equine gut is specially adapted to this. The horse has a tiny stomach and a large fermentation area to digest the herbage it has eaten. Whilst the horse grazes, it also walks around, helping the circulation of blood back up the leg to the heart.

It is important that the natural instincts of horses are met through correct management or horses may become depressed or 'sour' and

Figure 1.4 Breeding stock, including foals, may be transported abroad by plane.

uncooperative. Horses should be allowed to follow their natural instincts as much as possible. Given freedom to live as nature intended will result in healthier horses that are less likely to suffer from stress. This is particularly true of the competition horse that is often subjected to highly stressful situations including long-distance travel. Even breeding stock, including foals, may be flown abroad (Figure 1.4).

CLASSIFICATION OF LIVING ORGANISMS

Scientists have been placing organisms into groups, for the sake of comparison, for many years. As unknown organisms are found, a system of classification can help to identify them. The process of placing organisms into set groups is known as *taxonomy*.

Artificial classification

This old system used one characteristic of the organism to classify it, for example, all animals that can fly. This would include bats, birds and butterflies and obviously resulted in very different organisms in the same group.

Table 1.1 Classification of some members of the horse family.

Kingdom	*Phylum*	*Class*	*Order*	*Family*	*Genus*	*Species*
Animalia	Chordata	Mammalia	Perrisodactyla	Equidae	*Equus*	*caballus* (horse) *przewalskii* (Przewalskii's) *asinus* (donkey)

Natural classification

In the seventeenth and eighteenth centuries, two scientists, Carl Linnaeus and John Ray, developed a new, more natural, system of classification that put similar organisms in the same group. A system of smaller and smaller groups was used to classify organisms, ranging from *kingdom* to *species* (Table 1.1).

Carl Linnaeus also introduced a worldwide system known as the *Binomial System*, to help prevent confusion in naming organisms. Each organism is given two Latin names, the first being the name of the genus and the second the name of the species:

- *Equus caballus* – modern horse
- *Equus przewalskii* – Przewalskii's horse
- *Equus asinus* – donkey

The genus is always capitalised and the species is always in lower case. The name should be italicised.

Kingdom

There are five kingdoms in most modern systems:

- Animalia – all multicellular animals
- Plantae – multicellular plants that photosynthesize
- Monera – bacteria and blue-green algae
- Protista – paramecia and amoebae
- Fungi – mushrooms and toadstools

Phylum

The Kingdom Animalia is divided into 27 phyla. The horse family belongs to the phylum Chordata.

Class

Phyla and subphyla are further divided into classes:

- Amphibia – frogs and toads
- Reptilia – turtles, snakes, lizards
- Aves – birds
- Mammalia – mammals

The horse family belongs to the class Mammalia.

Order

Classes are subdivided into smaller groups called orders. The class Mammalia contains 18 different orders, including:

- Primates – humans, apes
- Perissodactyla – horses
- Artiodactyla – cows, pigs, sheep

Family

Orders and suborders are broken down into families. The horse's family is Equidae.

Genus and species

These are the final categories of the classification system. This provides the animal's scientific name, such as *Equus caballus*.

CHARACTERISTICS OF LIVING THINGS

Certain features are common to all living things, including horses. All living things, both plants and animals, have the following characteristics. They:

- **M**ove
- **R**espire – obtain energy from food
- Are **S**ensitive to stimuli
- Need **N**utrition
- **E**xcrete – get rid of waste substances produced in the body
- **R**eproduce – give rise to offspring
- **G**row – get bigger until they reach adult size

This list can be remembered by the mnemonic **MRS NERG**!

Movement is obvious in a horse, but not so much in a plant. Horses have a skeleton and muscles, which enable it to move. Although most plants are rooted to the spot, their leaves and stems may be observed to move, if very slowly. When looking at plant cells under the microscope, however, they may be seen moving at some speed.

Figure 1.5 Dressage horse moving sideways.

Horses are sensitive. If you squeeze with the leg when riding, a well-trained horse should move forward as a result (Figure 1.5). The squeeze of the leg is a *stimulus* and the *response* is movement. Horses respond to heat, light, touch, sound and chemical stimuli, such as smells. Plants also respond to stimuli, but this is a very much slower response than that of animals.

Horses build up huge amounts of waste materials from all the chemical reactions going on in their cells, and these waste products need to be removed so that they do not damage the body. This process is known as excretion.

All living things need food. Horses feed on complex organic substances that are then broken down by the process of digestion to smaller, simpler particles before being absorbed into the body (Figure 1.6) – this is known as *heterotrophic* nutrition. Plants are able to make their own food from simple substances, such as carbon dioxide and water using energy provided by sunlight – this is known as *autotrophic* nutrition.

Horses must reproduce, and this involves the union of the mare and stallion, a process known as sexual reproduction. Some organisms may

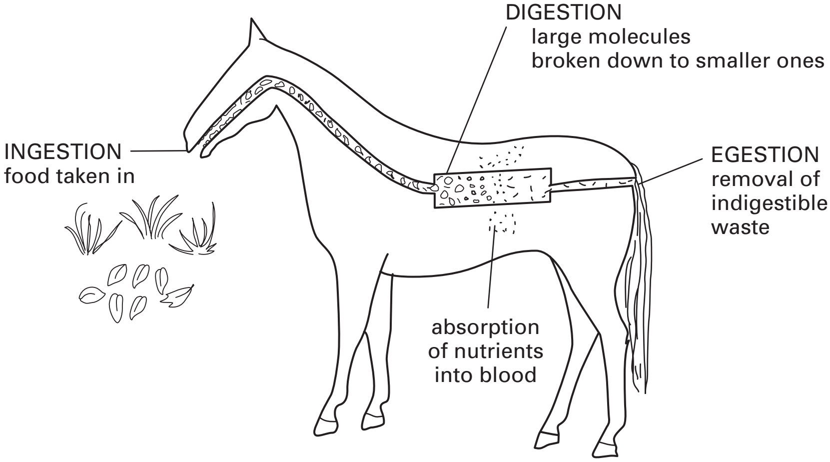

Figure 1.6 How horses digest their food.

reproduce themselves without the need for a partner and this is known as asexual reproduction.

THE HORSE'S BODY

The horse's body may be compared to a highly sophisticated machine, consisting of many different parts working together to enable the horse to live. Each of these parts has a specific function or job to do, which may be interlinked with one or several others.

Within the horse's body there are many layers of organisation and complexity:

Atoms → Molecules → Cells → Tissues → Organs → Systems

- A group of similar cells is known as a *tissue*
- A group of different tissues working together form an *organ*
- A group of organs working together create an *organ system*

For example:

Cells →	Tissue →	Organ →	System
Nerve	Nerve	Brain	Nervous System

The lowest level involves chemistry, i.e. atoms. Atoms combine to form a great range of molecules within the horse's body.

Examples of important biological molecules include:

- Water
- Carbohydrates – sugars, monosaccharides, disaccharides

- Amino acids and proteins
- Lipids (fats) – phospholipids
- Nucleic acids – DNA, RNA
- ATP – Adenosine triphosphate
- Enzymes – e.g. digestive enzymes
- Hormones – e.g. insulin, adrenalin

Cells are the smallest independent units within the body, and there are millions of them. They are specialised and perform different functions within the body, e.g. blood cells, bone cells, muscle cells, nerve cells, etc. Cells are tiny and cannot be seen by the naked eye – a microscope is required. Many cells with similar structure and function are grouped together in parts known as tissues. Examples include epithelial tissue, connective tissue, nervous tissue and muscle tissue.

Organs consist of a number of different types of tissue that together have a specific function, such as the heart, lung, liver, kidney and ovary.

Organs and tissues together work as systems required for the horse to live and survive as an individual. All these systems are required for the health of the horse.

Body systems

All the horse's body systems are interlinked in that they each have tasks to perform, but they are also dependent upon other systems.

- Respiratory system – takes air into the lungs, supplying oxygen to the body and removing waste carbon dioxide
- Cardiovascular system – heart and blood circulation; keeps the horse's body cells supplied with nutrients and oxygen and defends against disease
- Digestive system (digestive tract, pancreas, liver) – breaks down food into smaller substances that the body is able to use
- Nervous system (brain and spinal column) – control and communication network
- Endocrine system (hormones) – controls growth and internal co-ordination by chemical hormones
- Urinary system (kidneys, liver) – controls water balance
- Sensory system (eyes, ears, nose) – communicates information to the brain regarding the environment
- Reproductive system (ovaries and testes) – the smallest system, it is the only system which is different in males and females
- Musculoskeletal system – skeleton supports the body, protects major organs, provides an anchor for muscles

- Immune system – protects the horse against germs, includes white blood cells, antibodies and the lymphatic system
- Integumentary system – skin, hair, hooves, mane and tail

Movement of substances

Within the body, substances such as waste products, nutrients, hormones, etc. must move around to reach their target organs. Oxygen has to move from inhaled air and pass across the alveolar wall and then through the capillary wall deep within the lungs to reach the blood. Hormones must move from their point of manufacture to their target organs. Water, the main component of the horse's body, must move to allow distribution through the body, keeping substances (solutes) at proper concentrations to maintain the correct physiological balance. This is known as homeostasis.

Movement may occur through a variety of methods including:

- Diffusion
- Osmosis
- Active transport

Diffusion

Many substances pass in and out of cells by a process known as diffusion. Diffusion is the net movement of particles from an area of higher concentration to an area of lower concentration. There is a natural tendency for molecules to spread into all of the available space until they are evenly spread out.

Diffusion: A substance will always move from an area of high concentration to one of lower concentration, provided that there is no barrier to prevent it.

Larger molecules move at a slower rate, but the greater the difference in concentration (the concentration gradient) the faster the molecules will move. The concentration gradient can be thought of as downhill, requiring no energy to overcome. It is therefore a *passive* process. Cells take in oxygen and food for respiration from the blood and remove carbon dioxide and waste products by diffusion (Figure 1.7). The exchange of oxygen and carbon dioxide in the alveoli of the lungs also takes place by diffusion.

Facilitated diffusion

Scientists have found that some molecules are absorbed faster than others even when they have the same molecular formula, e.g. glucose

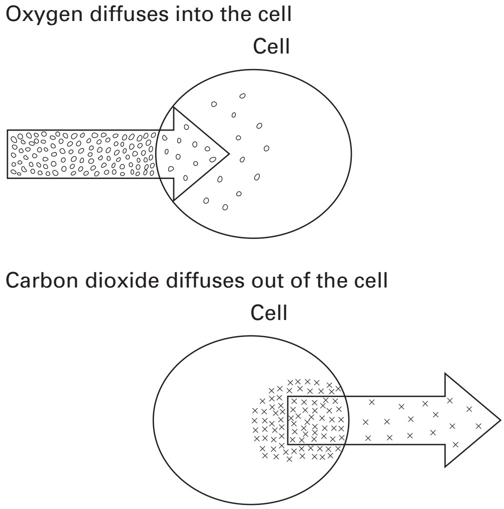

Figure 1.7 Diffusion of oxygen and carbon dioxide into and out of cells.

and fructose ($C_6H_{12}O_6$). Some particles, such as water and minerals, are also absorbed differently through the cells of the intestine. This is due to proteins within the cell membrane that provide 'channels' through which small water-soluble molecules such as glucose can pass. These proteins are known as *carrier* proteins and the process is known as *facilitated diffusion*. This process does not require energy.

Osmosis

All cells are surrounded by a cell membrane, which effectively has small holes in it. This allows some small molecules such as water to move through it. The membrane is therefore *partially permeable*. Water will actually move in both directions to attempt to even out the concentrations.

Osmosis is the process by which water moves from an area of high water concentration (weak solution) to an area of low water concentration (strong solution), through a partially-permeable or semi-permeable membrane.

If animal cells such as blood cells are immersed in water, there is less water within the blood cell than outside it, and so water will move into the cell by osmosis through the cell's partially-permeable membrane until the blood cell expands and eventually bursts. If the blood cell is placed in a more concentrated solution, water will move out of the blood cell into the surrounding solution and the cell will shrink.

Active transport

Sometimes cells need to move substances against their concentration gradient. This requires the use of energy. Some proteins within the cell membrane act as molecular pumps. These cells have an abundance of mitochondria providing ATP to power active transport. Examples of active transport are:

- Absorption of amino acids from the small intestine
- Excretion of urea from the kidney
- Exchange of sodium and potassium ions in nerve cells

Homeostasis

The horse's body must maintain a balance of many substances within it in order to work efficiently. There are many metabolic reactions constantly occurring within the cells, and enzymes control these reactions. To work properly, the correct environment of temperature, moisture, chemistry etc. is required. *Homeostasis* may be defined as the mechanism by which the horse's body maintains a constant internal environment.

Examples of homeostasis include:

- Maintaining body temperature – skin, liver and muscles
- Controlling blood sugar – pancreas, liver
- Controlling water balance – kidneys

Maintenance of body temperature is discussed in Chapter 8 and control of water balance is discussed in Chapter 5.

Control of blood sugar

The pancreas helps to maintain the level of glucose within the blood, so that there is enough for the production of energy through cellular respiration. The pancreas secretes two hormones into the blood:

- Insulin – secreted when blood sugar is too high, e.g. following high cereal starch feed
- Glucagon – secreted when blood sugar is too low, e.g. during prolonged exercise

Insulin is released as blood sugar increases. This causes the liver to take up glucose from the blood and store it as glycogen. Blood glucose levels then return to normal.

Glucagon is released as blood sugar falls, such as in prolonged exercise or starvation. Glucagon stimulates the liver to turn stored glycogen into glucose, which is then released into the blood thereby restoring glucose levels.

Summary points

- The horse has evolved over millions of years
- Changes to the overall size, limbs and head have resulted in the modern horse
- Evolution has affected the natural behaviour of horses
- Horses belong to the kingdom Animalia, phylum Chordata, class Mammalia, order Perissodactyla, family Equidae, genus *Equus*, species *caballus*
- All living things move, respire, are sensitive, need nutrition, excrete, reproduce and grow
- Cells are the smallest independent units within the horse's body
- Substances move within the body by various means, including diffusion, osmosis and active transport
- Homeostasis is vital for maintaining the balance of chemistry within the body