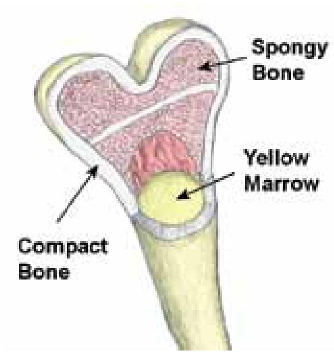
Katherine Staines

Exercise: working it to the bone

Obesity in Britain is on the rise and so we are all encouraged to do regular exercise, not only for our cardiovascular and respiratory health, but also for our general well-being. But what effects does exercise have on our bones, and why is this so important? Katherine Staines reports.

Our bones are alive

The skeleton is often thought of as dead tissue. However, the opposite is true. Bones are alive and able to respond to the changes they experience when you use them. The structure of bone makes it lightweight but strong and hard so it can support the body and protect its vital organs. It has a honeycomb-like internal structure composed of mineral crystals. These form when calcium and phosphate in bone cells undergo chemical reactions to produce the crystals that grow in size and make bones rigid.



Bone is a living tissue and its structure makes it lightweight (spongy bone) and yet strong (compact bone).

Bone consists of three cell types; osteoblasts, osteoclasts and osteocytes. Osteoblasts produce new bone while osteoclasts reabsorb bone by secreting enzymes to digest it. These two cell types work together to constantly renew our bones: our entire skeleton is replaced every 10 years. When an osteoblast completely surrounds itself with newly formed bone, it becomes an osteocyte. The structure of an osteocyte is unique – it has long processes that extend throughout a bone. Osteocytes are the most numerous cell type but the least is known about them. This is why this cell is becoming more interesting to research.

Key words
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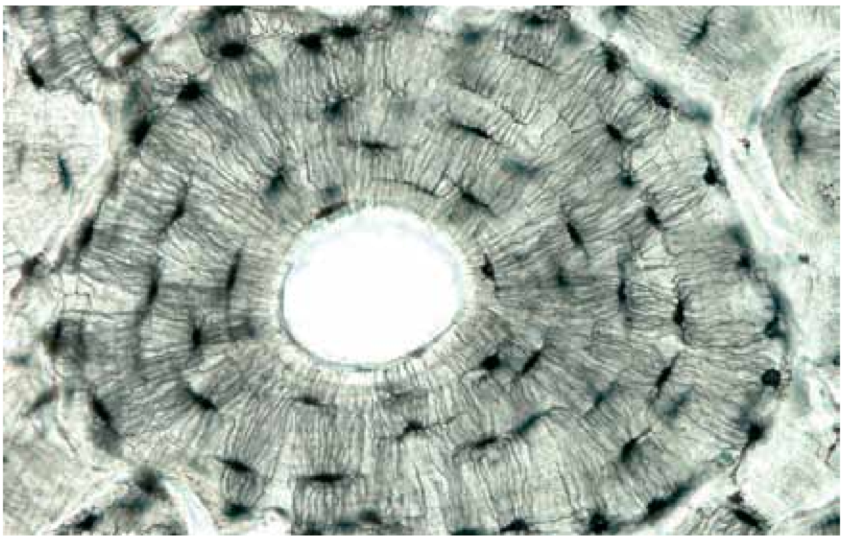

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Osteocytes are arranged in bone in circular layers like an onion. In the middle is a canal with blood vessels and nerves. There are thousands of connections between the osteocytes sitting next to each other, and between those in the different layers. This has led scientists to believe that the osteocytes communicate with each other, and other bone cells.

Exercise builds your bones

Muscles get bigger and stronger as we use them, and shrink when we don't. Bones act in a similar way – the more you use them by exercising, the more dense and strong they become.

The most beneficial type of exercise for bones is the weight-bearing kind, for example weight-training, hiking, jogging, tennis and dancing. However, these must be done in moderation, especially in children so as not to prevent the longitudinal growth of their bones.

A recent craze in gyms is the vibrating plate. It claims to tone muscle, as well as build bone mass, simply by standing on it. Has the vibrating plate completely ruled out previous research and found a low impact sport that can build bones, or is it all just a clever sales idea? NASA-funded scientists certainly believe in it and have shown that standing on a vibration plate for 10-20 minutes every day could replace bone loss that is seen when astronauts go into space and experience weightlessness. However, more evidence needs to be gathered as this idea remains controversial and prolonged exposure may cause development of other health risks.

Dancing is a form of weight-bearing exercise which helps to build bone.

When we are born, our bodies cannot predict what level of activity we will do in our life – some people will remain as couch potatoes throughout their lives, and some will go on to become Olympic rowers. So, we have different skeletal requirements to which our bones adapt. But how does this happen?

In the 19th Century, Julius Wolff (a German anatomist) stated that a bone will change its mass and internal structure to best meet the mechanical demands placed upon it. Various experiments have explored this idea. One example: in 1977, Henry Jones and colleagues looked at the size of the upper arm in 84 professional tennis players by X-ray. They found that they had up to 35% more bone in their playing arm than their other arm. This clearly shows the effects exercise can have on bones.

Do you think Andy Murray has more bone in his right arm than his left?

So our bones can be thought of as self-regulating; they sense the loads placed upon them and adapt their strength to a level at which the bone can still safely function. So what could be this 'sensor'?

Bone v brain

The brain communicates with the rest of the body by sending impulses through its billions of neurons. Remarkably, it has been suggested that bones also function like this.

The internal structure of your bones is highly organised and its cells form a network. The long processes of the osteocyte make this cell type a candidate for what is equivalent to the neuron in the brain. It may sense the different forces applied to it as we exercise, and relay this information to the rest of the bone. They also have tight junctions (see Box 1) between their processes and the other bone cell types, which could act as a junction similar to a synapse.

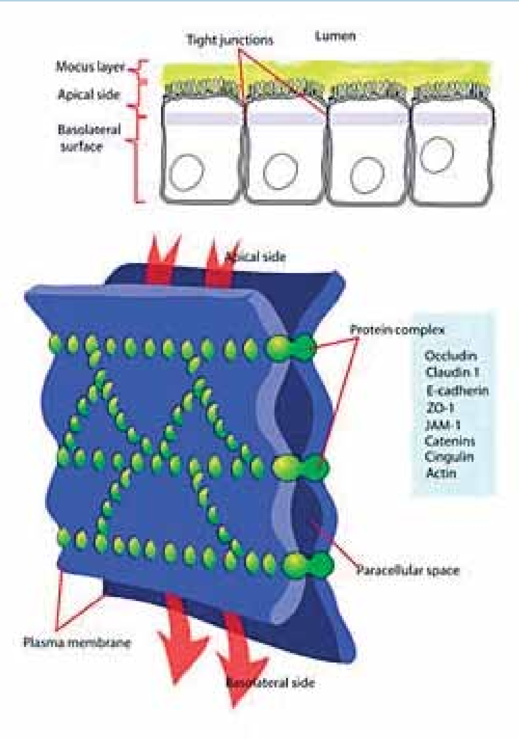
The most abundant chemical that is transported across a synapse in the nervous system is glutamate which is thought to be involved in our learning and memory. Studies have shown that bone cells have glutamate receptors, and function in a similar way to cells in the central nervous system. However this idea is controversial and work continues.

Box 1 Tight Junctions

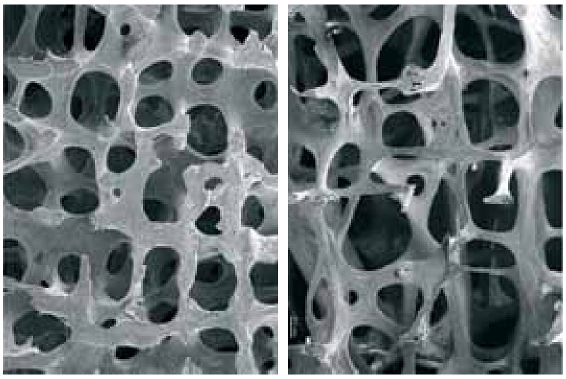
A tight junction is a point where the membranes of two cells become close together. Proteins, which are embedded in the outer membranes, join together to form strands which span the junction, much like beads on a string.

They have two main functions:

- they hold cells together;
- they act as a barrier, preventing the movement of molecules between the two cell, so molecules have to enter the cells by diffusion or active transport.



A tight junction keeps cells together and stops molecules passing between them. The plasma membranes of two cells are kept together by proteins which link together like beads on a string.



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This image was taken by an electron microscope. The left hand image is from a healthy person. It has a honeycomb structure which allows it to be lightweight. The right hand image is from someone with osteoporosis. The bone is thinner and has many more holes in it. This means it is more likely to break.

Why should we build our bones?

About 3 million people in the UK have osteoporosis which increases the risk of bones breaking. It is commonly thought to just affect older women but in fact can affect men and women at any age, and is caused by a loss of bone mass. The amount of bone you have increases up until the age of 30 at which it reaches its peak strength and density. After this, bone mass decreases at a gradually, but certain factors such as the menopause can accelerate this. The higher your peak bone mass, the longer it takes for it to fall to potentially dangerous levels.

Exercise is key to determining peak bone mass. Its main benefit is building bone strength and mass but it has other effects. It will assist joints, making them more flexible. However this must be done in moderation as it can put wear and tear on the joints. Exercise also reduces the risk of an injury, and can increase balance and flexibility.

The idea that genetics plays a large part in determining peak bone mass is new and is dominating research into osteoporosis. From looking at family histories and from studying twins (see Box 2), scientists have shown that up to 90% of peak bone mass can be inherited. They have also identified genes that, when mutated (faulty) have been suggested to cause the disease. These include the gene for the vitamin D receptor.

So when is the best time to "invest" in the health of your bones? Well now. Up to 90% of peak bone mass is acquired by age 18 in girls and by age 20 in boys.

Box 2 Twin studies

In the 1870s, Sir Francis Dalton (Darwin's cousin) recognised that twins could be used to study what he called "nature versus nurture".

Twins are unique: identical twins, from one egg split in two, are genetically identical. Non-identical twins (from two eggs and two sperm) only share half of their genes but will be brought up in the same environment.

Similarities between identical twins and non-identical twins are compared, allowing researchers to establish the percentages of a disease which are due to genetics, to a shared environment, and to events that happen to one twin but not the other.

The only department of twin research was set up to study the genetics of osteoporosis. It now has a database of over 10 000 sets of twins and looks at the role genes have in cardiovascular disease, the musculoskeletal system and ageing.

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