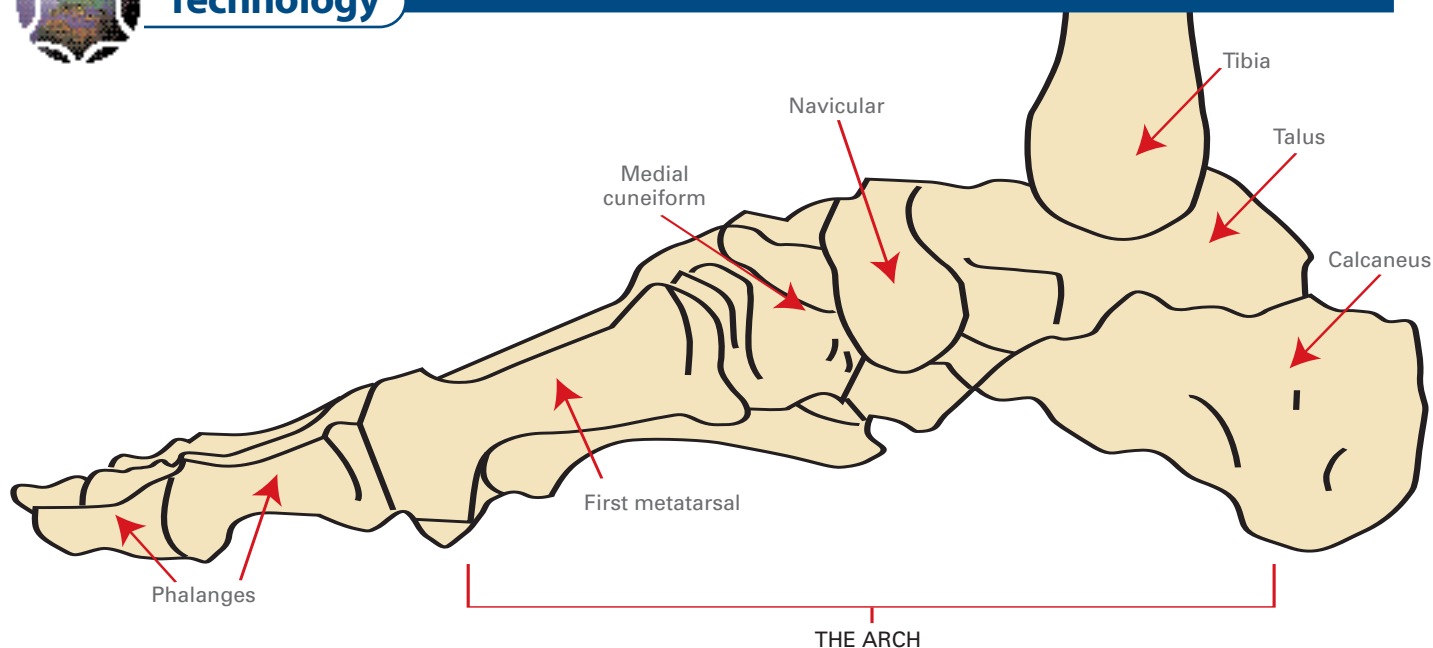




The whole foundation of designing a well fitting, comfortable shoe lies in understanding the nature of the foot for which it is intended. Considering the volume of leather used for shoes, Alan Weston, SATRA Technology Centre, provides a timely reminder of the structure of the foot and how footwear can enhance or damage its function.

26 bones, 107 ligaments and 19 muscles

The foot is a very complex and complicated structure. It is made up of twenty-six bones held in their correct positions with one-hundred-and-seven ligaments. In turn, the bones are linked to nineteen muscles by tendons that create movement (*Figure 1*). Additionally, the foot is supplied with nerves that link the tissues to the brain and blood vessels to carry minerals and proteins to maintain the tissue and fatty tissue to cushion and protect the bones. All are covered by skin encompassing nerve endings to sense pain, heat and cold, as well as hair follicles and sweat glands. The hair and sweat glands play an important role in temperature control and physiology.

Bones

The twenty-six bones of the foot are normally divided into three groups; tarsus, metatarsus and phalanges. The tarsus group consists of seven bones - the largest of which is the calcaneum (heel bone), falling at the back and bottom of the foot. The metatarsus group consists of five bones called metatarsals. The first metatarsal is the thickest, the second is the longest. The fifth metatarsal has a tuberosity (a prominence) at its base, which can be felt on the outer edge of the foot. The phalanges are the toe bones. The first toe has two bones, the other toes have three bones each - making fourteen in all. The lower leg comprises two bones: the tibia and the fibula. The bases of these form the socket into which the uppermost bone of the foot (talus) fits to form the ankle joint. Bone is formed by calcium phosphate being deposited to form a strong, light, honeycomb structure. This process takes place surprisingly slowly and is not completed until late into teenage years. As a result, there is

little structure to the foot of a child and it can be easily and permanently deformed without the child experiencing discomfort. Therefore special care is needed in designing and fitting children's footwear.

Arches of the foot

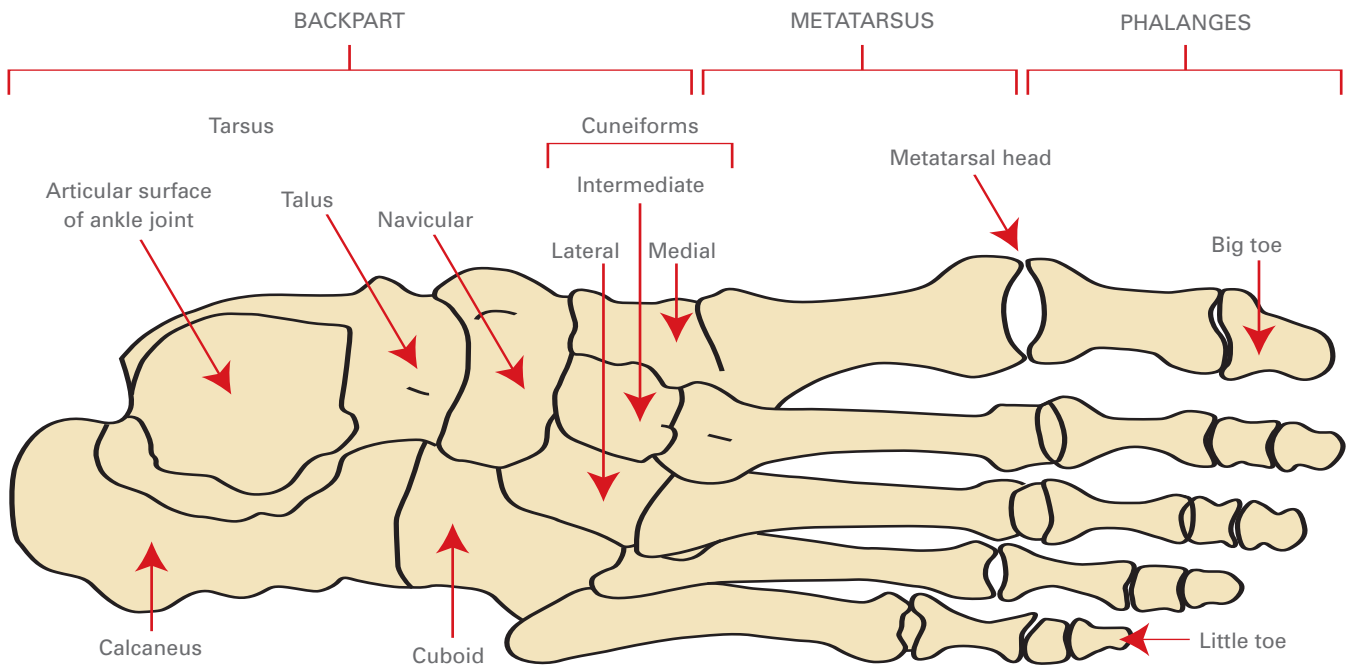
The bones of the foot are structured in the form of two arches. The longitudinal arch, the height of which varies from person to person, is between the heel bone and head of the first metatarsal. The absence of this arch gives rise to the condition known as flat feet and it is sometimes claimed that people with low arches may encounter a greater number of foot problems. When not under load, the foot also has a transverse arch at the base of the metatarsals, but under load this arch flattens and the foot becomes wider as the bones spread.

Gait

In walking, not only does the foot have to provide support for the body but also propulsion. A step follows a well-defined pattern. Initially, the heel contacts the ground towards its outer side. When the forefoot contacts, the foot rolls inwards and the point of maximum pressure runs along the outer border of the foot to the outer joint. As the heel lifts to flex the foot, the pressure transfers towards the inner joint. Finally, pressure transfers to the big toe as the body is propelled forward.

The effects of footwear on the foot

Footwear was originally produced primarily to protect the foot. With the progress of time, dictates of fashion have become key

**Figure 1**

influences and designs are not always fully functional! Care has therefore to be taken in designing both the last and the footwear to ensure they cause the minimum disruption to foot function, as well as providing a good fit and being comfortable. The shape of the last, in particular, can have a profound influence on the foot. As previously indicated, it will affect the growth of a child's foot if not designed correctly, but it can also have a significant influence on adult feet. *Figure 2* shows the degree to which a woman's foot can be distorted in a tight fitting court shoe or pump.

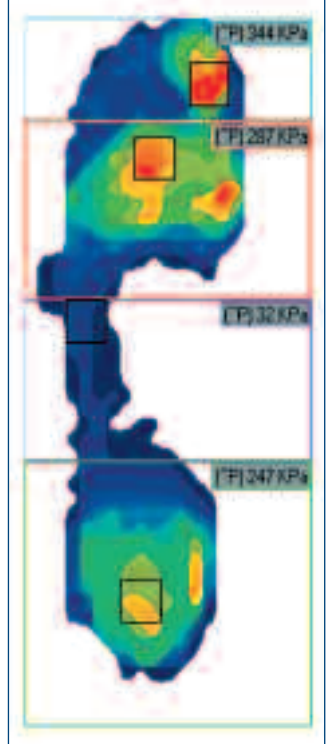
Pressure underfoot

Although there are large differences between individuals, the arches of the foot give rise to a typical pattern of pressure contact between foot and ground. *Figure 3* shows a pattern generated by pressure measuring sensors - the different levels of pressure are indicated by different colours. SATRA's research has shown that footwear can have a significant effect on this distribution of pressure. For example, by changing the surface shape or the hardness of insock and midsole materials, it is possible to redistribute the pressure, so avoiding high spots, which may cause discomfort or pain. Interposing arch supports or metatarsal pads into the footwear creates the opportunity to change the action of the foot by changing the pressure distribution. However, this needs to be done carefully so as not to cause discomfort or adversely affect foot function.

The heel height of a shoe also has a key influence on foot function. When standing or walking barefoot, a greater proportion of the body load is generally taken by the heel than the forefoot. However, in a high-heel shoe, the weight transfers forward onto the metatarsals and toes. This can affect both posture and mode of walking.

Flexing and toe spring

In an unrestrained state, the foot will normally flex in the joint region by approximately 50 degrees during the 'take-off' phase of a walking step. If the footwear prevents this occurring, perhaps because the construction is too stiff, the dorsal surface of the foot

Figure 2**Figure 3**

will press up against the upper causing discomfort and tiredness. This can be overcome to some extent by introducing toe spring into the footwear. The amount of spring needed is dependent on a number of factors, for example, heel height. The higher the heel, the less toe spring is needed to compensate for flexing. In the extreme, a shoe with a rigid bottom - such as a clog - allows no foot flexing and needs enough toe spring for the shoe to rock right over into the take-off position. These examples show that great care is needed to ensure that both the last and footwear are designed to take account of foot function, fit and comfort. 🌐