COUNTING SYSTEMS AND NUMERALS

Nature's abacus

Soon after language develops, it is safe to assume that humans begin counting - and that fingers and thumbs provide nature's **abacus**. The decimal system is no accident. Ten has been the basis of most counting systems in history.

When any sort of record is needed, notches in a stick or a stone are the natural solution. In the earliest surviving traces of a counting system, numbers are built up with a repeated sign for each group of 10 followed by another repeated sign for 1.

Egyptian numbers: 3000-1600 BC

In Egypt, from about 3000 BC, records survive in which 1 is represented by a vertical line and 10 is shown as ^. The Egyptians write from right to left, so the number 23 becomes lll^^

If that looks hard to read as 23, glance for comparison at the name of a famous figure of our own century - Pope John XXIII. This is essentially the Egyptian system, adapted by Rome and still in occasional use more than 5000 years after its first appearance in human records. The scribes of the Egyptian pharaohs (whose possessions are not easily counted) use the system for some very large numbers - unwieldy though they undoubtedly are (see **A large Egyptian number**).

Babylonian numbers: 1750 BC

The Babylonians use a numerical system with 60 as its base. This is extremely unwieldy, since it should logically require a different sign for every number up to 59 (just as the decimal system does for every number up to 9). Instead, numbers below 60 are expressed in clusters of ten - making the written figures awkward for any arithmetical computation.

Through the Babylonian pre-eminence in **astronomy**, their base of 60 survives even today in the 60 seconds and minutes of angular measurement, in the 180 degrees of a triangle and and in the 360 degrees of a circle. Much later, when **time** can be accurately measured, the same system is adopted for the subdivisions of an hour.

The Babylonians take one crucial step towards a more effective numerical system. They introduce the place-value concept, by which the same digit has a different value according to its place in the sequence. We now take for granted the strange fact that in the number 222 the digit '2' means three quite different things - 200, 20 and 2 - but this idea is new and bold in Babylon.

For the Babylonians, with their base of 60, the system is harder to use. For them a number as simple as 222 is the equivalent of 7322 in our system (2 x 60 squared + 2 x 60 + 2).

The place-value system necessarily involves a sign meaning 'empty', for those occasions where the total in a column amounts to an exact multiple of 60. If this gap is not kept, all the digits before it will appear to be in the wrong column and

will be reduced in value by a factor of 60.

Another civilization, that of the **Maya**, independently arrives at a place-value system - in their case with a base of 20 - so they too have a symbol for zero. Like the Babylonians, they do not have separate digits up to their base figure. They merely use a dot for 1 and a line for 5 (writing 14, for example, as 4 dots with two lines below them).

Zero, decimal system, Arabic numerals: from 300 BC

In the Babylonian and Mayan systems the written number is still too unwieldy for efficient arithmetical calculation, and the zero symbol is only partly effective.

For zero to fulfil its potential in mathematics, it is necessary for each number up to the base figure to have its own symbol. This seems to have been achieved first in India. The digits now used internationally make their appearance gradually from about the 3rd century BC, when some of them feature in the inscriptions of **Asoka**.

The Indians use a dot or small circle when the place in a number has no value, and they give this dot a **Sanskrit** name - *sunya*, meaning 'empty'. The system has fully evolved by about AD 800, when it is adopted also in **Baghdad**. The **Arabs** use the same 'empty' symbol of dot or circle, and they give it the equivalent Arabic name, *sifr*.

About two centuries later the Indian digits reach Europe in Arabic manuscripts, becoming known as Arabic numerals. And the Arabic *sifr* is transformed into the 'zero' of modern European languages. But several more centuries must pass before the ten Arabic numerals gradually replace the system inherited in Europe from the **Roman** empire.

The abacus: 1st millennium BC

In practical arithmetic the merchants have been far ahead of the scribes, for the idea of zero is in use in the market place long before its adoption in written systems. It is an essential element in humanity's most basic counting machine, the **Abacus**. This method of calculation - originally simple furrows drawn on the ground, in which pebbles can be placed - is believed to have been used by Babylonians and Phoenicians from perhaps as early as 1000 BC.

In a later and more convenient form, still seen in many parts of the world today, the abacus consists of a frame in which the pebbles are kept in clear rows by being threaded on rods. Zero is represented by any row with no pebble at the active end of the rod.

Roman numerals: from the 3rd century BC

The completed **decimal system** is so effective that it becomes, eventually, the first example of a fully international method of communication.

But its progress towards this dominance is slow. For more than a millennium the numerals most commonly used in Europe are **those evolved in Rome** from about the 3rd century BC. They remain the standard system throughout the Middle Ages, reinforced by Rome's continuing position at the centre of western civilization and by the use of Latin as the scholarly and legal language.

Binary numbers: 20th century

Our own century has introduced another international language, which most of us use but few are aware of. This is the binary language of computers. When interpreting coded material by means of electricity, speed in tackling a simple task is easy to achieve and complexity merely complicates. So the simplest possible counting system is best, and this means one with the lowest possible base - 2 rather than 10.

Instead of zero and 9 digits in the decimal system, the binary system only has zero and 1. So the binary equivalent of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 is 1, 10, 11, 100, 101, 110, 111, 1000, 1001 and 1010. and soinfinitum.

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