HSS 102

Jan 12 and Jan 14, 2016

Lecture #2-3

Ancient Civilizations: The Invention of Writing and Numbers

Today, we will look at the beginnings of writing – both alphabet and numbers in ancient civilizations that date back to around 4,000 BCE.

We will first look at archeological evidence for the invention of writing, and then look at beginnings of mathematics. The ability to write and read and to do basic arithmetic is fundamental to any activity that remotely resembles science.

We will be paying attention to three ancient civilizations:

1. The Mesopotamian civilization (between the rivers Tigris and Euphrates, the present day Iraq)
2. The Egyptian civilization (around the river Nile, in the present day Egypt.
3. The Indus Valley (along the river Indus, or Sindhu, in the present-day Pakistan.)

## Definitions

Before we get into the details, let us get familiar with some terms we will be using throughout this course:

1. CE and BCE: CE stands for “Common Era” and BCE for “Before the Common Era.” We will be using these notations instead of the “BC”(Before Christ) and “AD” (Anno Domini).

Remember in BCE, larger numbers means *earlier* than present, while larger the number of the year in CE means *later* than the present. For example 500 BCE is earlier than 300 BCE, while 500 CE is later in time than 300 CE.(see the ppt )

1. Prehistory v. History

* Ancient history of very early era is further divided into:  
  *Pre-history*: the enormously long time period before writing is invented. In other words, prehistoric cultures have no written records. We know these pre-literate cultures only through the archeological remains including things like cave paintings, remains of their settlements, pottery, tools etc.

## From oral cultures to writing:

Development of writing was a giant step forward for the entire human race. Writing was a perquisite for any kind of systematic science to start.

What is writing?: reduction of speech (spoken sounds/words) to graphic forms.

What difference does writing make to growth of knowledge:

1. Writing breaks the flow of spoken language and sets ideas down in words. This makes it possible to see the logical structure of the argument.
2. Writing makes it is easier to see contradictions partly because one can formalize statements and compare them side by side. Writing makes it possible to stand back and examine a text in a more abstract and rational manner. Criticism is essential for growth of knowledge.
3. Writing frees minds from the need to memorize vast amounts of facts and figures.
4. Writing allows greater abstractedness and de-contextualization.

### Evolution of writing:

Growth of writing, mathematics and science is intimately connected to the development of city-based/urban civilizations with a complex division of labor. A class of workers (priests, clerks, teachers and etc. ) emerges whose job it is to deal with symbols…

The first urban civilization arose in the Mespotamia around 4000 BCE. This was followed by Egypt around the river Nile and later by Mohanjodaro and Harappa along the Indus

## Mesopotamian Civilization

Sumerian **cuneiform** writing on clay tablets is the earliest form of writing that we know of and can read.

Writing emerged in the context of temple bureaucracy in the cities of southern Iraq: a tiny number of accountants used word signs (pictograms) and number signs to account for property – how many animals, how much land, how many sacks of grain etc. They wrote on clay tablets, about the size of a credit card but about one cm thick. They used a reed stylus to make the mark on wet clay – used a pointed stylus for objects and a rounded stylus for numbers. These clay tablets were dried in the sun, and could be recycled later when no longer needed. Some of the tablets got baked in accidental fires: while fire destroys all other written texts, fires helped preserve the cuneiform tablets.

Cunieform script underwent gradual evolution from just pictographic record-keeping to a real language in which gods could be praised, stories could be told and passage of stars could be recorded and mathematical problems could be solved. This evolution is evident from tablets unearthed from three archeological sites:

1. Remains of a school house, “House F” excavated in 1950 from a small house near Najaf in modern Iraq. This “House F” was most probably a school for scribes – students learning to write in cuneiform. Most of the tablets are school exercises in which students simply copy. A small number of tablets record stories about gods and heroes and even have funny stories about the students of the school. These tablets go back to around 1740 BCE, the reign of the King Hammurabi (1792-1750 BCE)
2. The library of Ashurbanipal, King of Assyria (from 668 bce to around 630 bce), on the banks of Tigris river in modern day Mosul, Iraq. British Museum archaeologists discovered more than 30,000 cuneiform tablets and fragments from this site. Alongside historical inscriptions, letters, administrative and legal texts, were found thousands of divinatory, magical, medical, literary and lexical texts.

One of the most famous finds from this library is the Flood tablet (see PowerPoint). It is a fragment from the Epic of Gilgamesh – the first epic poem in world literature. It tells the story of the hero Gilgamesh, who sets off on a quest for the secret of eternal life. He confronts demons and monsters, he survives all kinds of perils and eventually he has to confront the deepest challenge of all: his own nature and his mortality. The flood tablet is a part of the Gilgamesh epic. The tablet was deciphered in 1872 by George Smith, an apprentice to a printer, who got interested in Sumerian tablets at the British museum. He discovered that the tablet told the story of the Great Flood and Noah’s ark. The tablet dated back to 700 bce, roughly 400 years before the Old Testament or the Hebrew Bible was written.

The temple to sky-god Anu: scholarly tablets from the chief-priest of the sky god Anu in the city of Uruk in 190 bce: here we encounter mathematical astronomy containing complex instructions for calculation of dates and positions of key events in the journey of mars, Jupiter and moon and tabulation of data….

### Writing in Egypt:

“Books” –or rather, scrolls -- in Egypt, classical Greece and Rome were made of papyrus.

Egypt was the only country where papyrus was made and shipped to all places around the Mediterranean.

Papyrus is made from a plant called papyrus which grows in the swamps of the Nile delta. The plant can grow as tall as 15 feet. The pith of the plant is cut into thin slices, soaked and pressed together to form sheets which are later smoothed by stones. These sheets were used for writing using a reed pen and permanent ink made out of minerals.

#### Writing in the Indus Valley Civilization

Indus valley civilization lasted from approximately 2300 to 1500 BCE

* Largely agricultural economy, but also trade in gold, copper, timber, ivory and cotton with Mesopotamia – Indus seals have been found as far in as Central Asia and what is now called Middle East.
* impressive urban centers at Mohanjo-Daro (in Sindh, Pakistan), Harappa (200 miles to east), Lothal (gurjarat) and 800 miles along the Arabian coast of India.
* Literate culture, with a script which has not yet been deciphered -- seals.

The cow/unicorn seal: discovered in Harappa (150 miles south of Lahore) in the 1850s . Made of soap stone, the size of a postage stamp.

Script: the tablets have some kind of writing but it has not yet been deciphered. Scholars now believe that the IV script is not a complete language but rather symbols to identify a product or to indicate a place of origin of a person or a product. These tablets were more like tags or identity cards.

# The beginnings of writing in India:

Indus Valley has left some kind of writing on their seals but no one has been able to decipher it yet.

So when does actual writing make an appearance in the Indus Valley and the later Vedic civilization?

First records of writing come from the Mauryan king, Ashoka in 260 bce written in Brahmi – first pan-Indian language, from northern Afghanistan to Karnataka

Sanskrit: even though Sanskrit is much older than Brahmi, there are no written records dating back to the time of the Rg Veda (the first of the four Vedas). The reason is that Sanskrit was considered a sacred language, the language of Gods, which was not to be written. Sanskrit texts were passed on through generations through memory.

# The Evolution of Numbers

What is place value?

Place value, also called positional notation, has been described as “one of the most fertile inventions of humanity, comparable to the invention of the alphabet which replaced thousands of picture-signs.”

In the place-value method of writing numbers, *the position of a number symbol determines its value.* In other words, the position dictates the power of the base that is to be multiplied by the number in question. Consider the number 211 written in our modern decimal notation: the numeral 1 has the value of one if it occupies the first place from the right, but the same 1 stands for a ten as it moves one place to the left. Similarly, 2 is not simply the sum of one and one, but has the value of two-hundred. If the order changes, the value changes; for example, 112 is a very different number from 211.

Consider a larger number: 4567. If we stop to think about it, this number is actually made up of the following: 4x1000 + 5x100 + 6x10 + 7x1. In other words, every position from right to left is a multiple of 10 (unit (1), tens (10x1), hundred (10x10, or 102), thousand (100x10, or 103) and so on to millions, billions, trillions, etc. If we accept this rule, then instead of explicitly spelling out the powers –four thousand, five hundred, sixty seven, we simple assume the we assume that in this case, 4 is to be multiplied by 103, 5 by 102  and so on.

**The beauty of place value—and the reason it is considered revolutionary—is that it allows you to write any number, however large or small, with just a few numerals**. Using the modern decimal system, nine digits (1 to 9) and a zero are sufficient to write any number without having to invent new symbols for each number, or for each multiple of 10.

If the place value notation did not exist, separate symbols would be required for writing 10, 20,30, … 90 and for 200, 300 … 900. Let us take an example. We know from the existing evidence examined in more details in later sections), that in India place-value notations first made their appearance around the time of Asoka around 300 BCE, while the ancient Greeks never developed it at all. Thus, someone living *before* the Asokan era in India would write the number 456 (for example) in Brahmi by using a symbol for 400, followed by a separate symbol for 50 , followed by a symbol for six. Similarly, his Greek counterpart would write the same number as *υνϛ*, where these letters from the Greek alphabet stand for 400, 50 and 6 respectively. To contrast, in a positional value notation (in our example 456), the numeral 4 would stand for 400 (4 units at the 100th position), five would stand for 50 (five units at 10th position) and six for 6 units. In other words, the order in which the numerals are written or spoken would *automatically* indicate whether they represented a thousand, hundred etc. In this system, the work of “power words”—special words or signs indicating numerical rank (thousand, hundred, tens etc.)—is simply transferred to the places any of the first 9 numerals occupied.

Human beings, and even primates, have an innate ability to count. Counting (like the ability to speak) is as old as humanity itself.

The most important achievement of ancient civilizations is the ability to represent and record what they count with numbers: **just like alphabets are graphic representations of the sounds of spoken language, numbers are graphic representations of the number of things counted**.

Even more important than development of number systems is the invention of **place-value, or positional value.**

**Place value is a necessary pre-requisite for the emergence of zero or empty space**:

What does place value notation have to do with zero?

The answer: *Zero was born out of place value notation*. To be more precise, place value is *necessary* for the evolution of zero as a numeral, but it is *not sufficient*, for you can have place value without a zero if you have number words that are larger than the base. For example, you could write or say 2004 as “two thousand and four,” without using a zero. But if you are writing in numerals, you cannot write 2004 without indicating that there is nothing under tens and hundreds — and zero is what indicates the absence of any number, or the presence of nothing. Without some way of indicating nothing, the numerals 2 and 4 could well mean 24 or 204. As Georges Ifrah put it in his well-known book, *The Universal History of Numbers:*

In any numeral system using the rule of position, there comes a point where a special sign is needed to represent units that are missing from the number to be represented… It became clear in the long run that *nothing* had to be represented by *something.* The something that means nothing, or rather the sign that signifies the absence of units in a given order of magnitude is …[ what we call zero.]

As the above example shows, the philosophers and scribes who used number words could get by without having a special numeral that indicated nothing. But it is also important to note that the need for zero was not obvious to those who practiced everyday mathematics in their daily lives. As Alfred North Whitehead put it, “the point about zero is that we do not need to use it in the operations of daily life. No one goes to buy zero fish.” Charles Seife, whose book this quote is taken from, goes on to add, “you never need to keep track of zero sheep or tally your zero children. Instead of ‘we have zero bananas,’ the grocer says, “we have no bananas. *We don’t have to have a number to express the lack of something*.”

It is only when numbers are written as numerals or as number-symbols in a positional order, does the need for a zero emerge. In other words, when 10-based numerals began to be arranged according to their rank, the symbol for zero became necessary.

**There are four ancient civilizations where we find the development of place-value numeration and they are:**

1. The Mesopotamian civilization
2. China
3. India
4. The Mayans of South America. [will not be considered here as they did not influence the development of mathematics in the rest of the world. Remember: the Americas were not known to other civilizations until 1492 when Christopher Columbus reached their shores).

The Greeks and Romans did not develop place value.

**Numbers in the Mesopotamian Civilization:**

How the mathematics in the tablets was deciphered

The cuneiform script of Mesopotanian civilization had been successfully deciphered starting from around 1800s by European and British travelers, explorers and colonial officers.

The **Behistun Inscription** (also **Bistun** or **Bisutun**, [Modern Persian](http://en.wikipedia.org/wiki/Modern_Persian) and [Kurdish](http://en.wikipedia.org/wiki/Kurdish_language): بیستون < [Old Persian](http://en.wikipedia.org/wiki/Old_Persian): **Bagastana**, meaning "the place of god") is a multi-lingual inscription located on [Mount Behistun](http://en.wikipedia.org/wiki/Mount_Behistun) in the [Kermanshah Province](http://en.wikipedia.org/wiki/Kermanshah_Province) of [Iran](http://en.wikipedia.org/wiki/Iran), near the city of [Kermanshah](http://en.wikipedia.org/wiki/Kermanshah) in western Iran.The inscription includes three versions of the same text, written in three different [cuneiform script](http://en.wikipedia.org/wiki/Cuneiform_script) languages: Old Persian, [Elamite](http://en.wikipedia.org/wiki/Elamite_language), and [Babylonian](http://en.wikipedia.org/wiki/Babylonian_language) (a later form of [Akkadian](http://en.wikipedia.org/wiki/Akkadian_language)). In effect, then, the inscription is to [cuneiform](http://en.wikipedia.org/wiki/Cuneiform_script) what the [Rosetta Stone](http://en.wikipedia.org/wiki/Rosetta_Stone) is to [Egyptian hieroglyphs](http://en.wikipedia.org/wiki/Egyptian_hieroglyph): the document most crucial in the [decipherment](http://en.wikipedia.org/wiki/Decipherment) of a previously lost [script](http://en.wikipedia.org/wiki/Writing_system).

But the credit for deciphering the number system and the mathematical operations goes mostly to Otto Neugebauer (1899-1990) , an Austrian-born American mathematician and historian of mathematics at Brown University. O.N. was trained as an engineer who got interested in ancient mathematics. His Ph.D. was on Egyptian math. In 1927 he got interested in Babylonian math, about which nothing much was known at that time. He learnt Akkadian which is the language in which the Babylonians wrote their tablets. He published his 3-volume collection on mathematical tablets in the mid-1930s. They established the great richness of Babylonian mathematics, far exceeding anything one could have guessed from Greek or Egyptian sources.

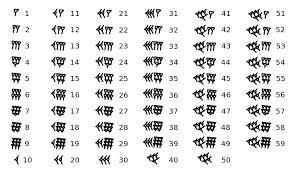
After the rise of Hitler, he had to leave for the United States. Brown University in Rhode Island hired him as a professor where he set up the prestigious history of mathematics department. O.N. trained a new generation of scholars, including David Pingree (1933-2005) who extended the interest in ancient math to India. Pingree has trained another generation of historians of Indian math, notably Kim Plofker who has written a new book Mathematics in India (2009).

ON’s book, *The Exact Sciences in Antiquity* was published in 1952 and is still considered a classic in history of math.

Babylonian Numerals:

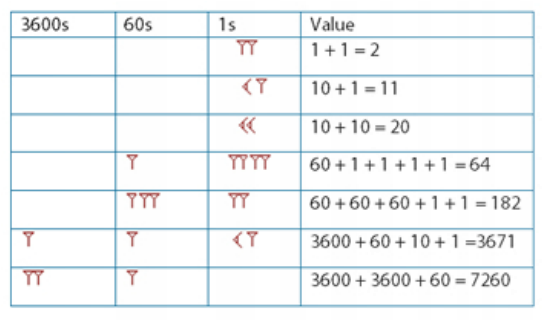
The tablet writers back in Mesopotamia only needed two symbols to write any number under the sky:[Babylonian 1.svg](http://en.wikipedia.org/wiki/File:Babylonian_1.svg) to count units, and [Babylonian 10.svg](http://en.wikipedia.org/wiki/File:Babylonian_10.svg)to count tens.

See the chart for numbers 1-59



After 59, they would start with a single wedge, bigger in size, again which would represent 60. 61 would be [Babylonian 1.svg](http://en.wikipedia.org/wiki/File:Babylonian_1.svg).[Babylonian 1.svg](http://en.wikipedia.org/wiki/File:Babylonian_1.svg) But if the scribe forgot to make the first wedge bigger, then how we distinguish between 61 and two? That is a real problem.

This was solved by positional system: the same symbol would have a different value depending upon the place: e.g. each 1 in the number 111 has a different value: from right to left, they stand of one, ten and hundred. Similarly the symbol [Babylonian 1.svg](http://en.wikipedia.org/wiki/File:Babylonian_1.svg) in [Babylonian 1.svgBabylonian 1.svgBabylonian 1.svg](http://en.wikipedia.org/wiki/File:Babylonian_1.svg)stood for “one”, “ sixty” and “thirty six hundred” in three different positions from the right to the left.



Zero as a place-holder:

See ppt.

**The Chinese “rod numerals”**

The earliest evidence of Chinese number-system comes from the so-called “oracle bones” inscribed with royal records of divinations written on bones and tortoise shells dating back to 1500 BCE (figure 1) These bones contain numerical records of tribute received, animals hunted, number of animals sacrificed, counts of days, months, and other miscellaneous quantities related to divination. Farmers found these bones in their fields in Henan Province at the end of the 19th century. Initially, they were thought to be “dragon” bones with medicinal value. Fortunately, they were rescued before they could be powered and sold as medicine. Many more bones carrying similar inscriptions have been found through the last century.

The oracle bones are mathematically important because they show an advanced numeral system, which allowed any number, however large, to be expressed by the use of nine unit signs, along with a selected number of “power-signs” for representing powers of tens, twenties, hundreds, thousands etc. The standard number system used today in China is a direct descendant of the ancient Shang system.

 But a distinct use of decimal place value – where the position of a number decides its value, complete with empty space indicating absence of any numeral—was already a common, everyday practice in China 400 years before the first millennium of the Common Era.

Alongside the written number ideograms (which date back to 1500 BCE oracle bones) the Chinese had their “counter-culture” rooted in practice: their “counters” were counting rods which were moved on any flat surface marked into successive powers of tens. These rods were not a mere accounting device but were used for all basic arithmetical operations and eventually also for solving algebraic equations. If the Chinese had transferred their rod-numerals and the mathematical operations based upon them into writing, the result would be *identica*l to our modern numeration and mathematical operations like multiplication, division, root extraction etc.

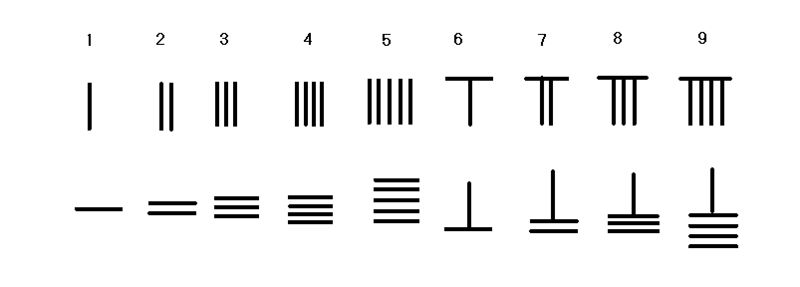
The rods were in use as far back 400 BCE (the Warring States era). The earliest physical rods unearthed by archeologists go back to around 170 BCE. Coins and pottery bearing rod-numeral signs have been dated to around 400 BCE. Records as far back as 202 BCE describe the first Han emperor as boasting that he alone knew “how to plan campaigns with counting rods in his tent.” These rods were basically short sticks about 14cm (5.5 inches) in length, made mostly of bamboo, but also of wood, bone, horn, iron or even ivory or jade (which only the very rich could afford). They were carried (all 271 of them) in a small hexagonal pouch, much like we carry electronic calculators or our smart phones today. Bags containing bundles of counting stick have been found in skeletal remains dating back to the last few centuries before the Common Era.

Who used them? Practically everybody : from traders, travelers, monks to government officials, mathematicians and astronomers. In other words, whenever and wherever computation was required, the sticks came out of their bags and spread on a mat, table top, floor or any flat surface. Evidence shows that during the Tang Dynasty (618-907), civil and military officials carried their bags of sticks wherever they went. The computations carried out with the sticks were written down on bamboo strips and on paper by the early centuries of the Common Era. (Paper was invented by the Chinese around 100 CE, though some archeological findings put the date as far back a century or two.)

Since counting with rods was a practical skill which everyone was supposed to be familiar with, early mathematical texts (such as the 3rd century CE *Nine Chapters on the Mathematical Arts*, and *The Mathematical Classic of Zhou Gnomon* that we referred to in the last chapter) don’t elaborate on how to use them. But a 4th century book attributed to a Master( Zi) Sun titled *Sun zi Suanjing* (the *Mathematical Classic of Master Sun*), provides details of how computation was to do be carried out with rods. This book was later included in the set of ten mathematical classics put together during the Tang Dynasty that all aspiring state officials had to study to pass the entrance exams. In the early centuries of the Common Era, rod numeral computations spread to Japan, Korea, Vietnam and other areas in South-East which were influenced by both India and China.

How were the rods used? The method is simple and ingenious.

The first nine numerals were formed using the rods in the following two arrangements, one in which the rods are vertical (*zong*) and the other in which the rods are horizontal (heng)



Counting rods placed vertically, *zong*, top row;

Rods arranged horizontally, *heng,* bottom row.

To write numbers greater than 10, the rods were set up in columns. The right-most column was for units, the next one for tens, the next the hundreds and so on. A blank column meant no rods were to be placed there, meaning what we mean today when we write a zero. The Chinese called the empty space in rod-numerals as kong, 空, which means empty, just as Hindus called an empty space “sunya.” To make it easier to read the columns, zongs and hengs were alternated: vertical arrangement of rods (zong) was used in the unit column, the hundreds column and ten thousand column and so on, while the horizontal (heng) arrangement used in tens, thousand, hundred thousand. Here are some illustrative examples:

1234 would be http://www-history.mcs.st-and.ac.uk/Diagrams/1234.gif

45698 would be   http://www-history.mcs.st-and.ac.uk/Diagrams/45698.gif

60360 would be http://www-history.mcs.st-and.ac.uk/Diagrams/60390.gif

The columns could be extended in *both directions,* with columns to the right of the units column containing negative numbers which were represented by rods of a different color. The rods were used for addition, subtraction, multiplication and division, the rules for which are laid out in Sun Zi’s book, which are translated and explained in *Fleeting Footsteps*. In fact, in her lecture when she was awarded the Kenneth May medal for her distinguished career, Lam Lay Yong took the audience step-by-step through the steps for multiplication and division that the great 9th century Muslim mathematician and astronomer al-Khwarizmi uses, to show that his method is *identical* to the method that Sun Zi lays out in his classic text.

**Evolution of numbers in India**

1. Vedas: very large numbers, but they are in number words.

Decimal: simply means counting in the bundles of ten.

Base 10: all Indo-European counting systems are decimal.

There is, of course, no doubt that as far back as we can go, Indians have used a decimal or a 10-based counting method. The *Rg-veda* and *Yajur-veda* provide ample evidence that by the early Vedic times, a regularized decimal system of number counting was well established. Kim Plofker has usefully provided English translations of shlokas from the Vedic corpus which give a good idea of how the power of ten was used. Two representative examples are quoted below.

You Agni, are the lord of all [offerings], you are the distributor of thousands, hundreds, tens [of good things.] Rg-veda, 2.1.8

Come Indra, with twenty, thirty, forty horses; come with fifty horses yoked to your chariot, with sixty, seventy to drink the soma; Come carried by eighty, ninety and a hundred horses” Rg-veda. 2.18:5-6.

By the middle-Vedic period, one finds number words for much larger powers of ten. A verse from Yajurveda (7.2.20) for example, offers praise to numbers which range from one, two … to *ayuta* (ten thousand), *niyuta* (hundred thousand), *prayata* (one million), *arbuda* (ten million), *nyarbuda* (hundred million), *samudra* (billion) *madhya* (ten billion), *anta* (hundred billion) *parardha* (trillion).

1. Concrete number system: Bhutasankhya

One, eka: that which is unique, eg. Surya, Chandra,

Two: netra, chakshu; ashvins (twins), hands,

Three: fires, triloka

Four: Vedas

Six: six limbs of the Vedas and so on…

Referred to as *Bhuta-sankhya* in medieval Sanskrit mathematical texts, this way of representing numbers is also called “object numbers” or “concrete numbers.” Rather than use the number word or a numeral, this system makes it possible to express any number by the name of whatever object—real or mythical—that routinely occurs in that number. Thus, the number two can be represented by all the Sanskrit words for “ eyes” because eyes naturally come in pairs. The symbols can also come from religious texts and ritual practices: thus the word “agni” can stand for number three, as there are three ritual fires; “anga” can stand for the number six, as there are six limbs of the Vedas. Alberuni, writing around the turn of the first 1000 years after the Common Era, describes this system thus:

… [for] each number, Hindu astronomers have appropriated quite a great quantity of words. Hence if one word does not suit the metre, you may easily exchange for a synonym which suits. Brahmagupta says: ‘if you want to write one, express it by everything that is unique, as the earth, the moon; two, by everything that is double e.g., black and white; three by everything which is threefold; the naught by heaven, the twelve by the names of the Sun.

This unique way of recording numbers arose out of the compulsion to write mathematical and astronomical ideas in verse so that they could be easily memorized. Our mathematically-minded poets faced a problem; it wasn’t easy to use number-words in verse all the time. They needed synonyms which would sound better and be easy to remember. These terse sutras were committed to memory, while the guru directly explained the full meaning to the students. Commentaries in prose were written to expound on the meaning of the symbols and the sutras.

The point is this: you can record, versify, and memorize number-words and concrete symbols, but you cannot compute with them. (Try adding “chakshu-akaash-agni” to “ashvin-anga-pitamaha,” or, even better, try multiplication or division!)

The way Sanskrit number-symbols, or *bhuta-sankhya*, were used is exemplified by the Yavana-jataka, or “Greek horoscopy”, of Sphujidhavja, which is a versified form of a translated Greek work on astrology. This text places the “wise king Sphujidhavja in the year Vishnu/hook-sign/moon” which translates into numerals one (moon), nine (hook sign) and one (the deity Vishnu) giving us the year 191 of the Saka era beginning in 78 CE. (The year corresponds to 269 or 270 CE.) More mathematical examples can be cited from Surya Siddhanta, an early 6th century text, and the 14th century writings of Madhava.

1. Aryabhatta’s numbering system :

**Aryabhata,** also called **Aryabhata I**or **Aryabhata the Elder**   (born 476, possibly Ashmaka or Kusumapura, [India](http://www.britannica.com/place/India)), astronomer and the earliest [Indian mathematician](http://www.britannica.com/topic/Indian-mathematics) whose work and history are available to modern scholars. He is also known as Aryabhata I or Aryabhata the Elder to distinguish him from a 10th-century Indian mathematician of the same name. He flourished in Kusumapura—near Patalipurta (Patna), then the capital of the [Gupta dynasty](http://www.britannica.com/topic/Gupta-dynasty)—where he composed at least two works, *[Aryabhatiya](http://www.britannica.com/topic/Aryabhatiya)* (c. 499) and the now lostAryabhatasiddhanta.

The underlying principle is this:

The consonants are assigned specific integer values, while vowels are used to represent decimal powers.

Consonants and vowels are combined to make syllables representing numbers. For example, the syllable gi would mean 3x102,, , while la would mean 50X101.

This ingenious system can represent even very large numbers with syllables.

The problem was that the syllables and words were hard to pronounce and remember. Here is a verse from Aryabhatiya:

“ the revolutions of the sun in a mahayuga are *khyu-ghr*, moon *ca-ya-gi-yi-nu-su-chlr,* earth *ni-si-nl-skhr,* eastward.”

This system proved to be too cumbersome and was soon forgotten.

Did he invent zero?

AB’s system is not place value and he nowhere uses zero as a number.

The claim that he invented zero is based upon his rule for extraction of extraction of square and cube roots. The idea is that he could not have done that unless he was familiar with zero and place value.

1. Brahmi numerals…. Devanagari – they are the ancestors of Hindu-Arabic numerals

But Brahmi has no place value

The oldest written script from the Indian subcontinent is that found on the yet un-deciphered Harrapan seals, but the oldest *deciphered* script is Brahmi that dates back to around 4th century BCE. The general consensus is that the Brahmi script was formalized at about the time of the Mauryan emperor, Ashoka. It was devised to give written expression to the spoken language of the region, called Prakrit. The earliest inscriptions in Brahmi can be found on the rock edicts installed by Ashoka, around the middle of the third century BCE. It is in these rock edicts we get the first glimpse of how numbers were written in Brahmi. Numerals 1,4 and 6 are found in various Ashokan inscriptions, while numbers 2, 4, 6, 7 and 9 in the Nana Ghat  inscriptions about a century later; and the 2, 3, 4, 5, 6, 7, and 9 in the Nasik caves of the 1st or 2nd century ce. See the ppt for a composite of Brahmi numerals obtained from sites all over the subcontinent, including Nepal.

There is a consensus among historians that *Brahmi numerals did not have a concept of place value and did not have a symbol for zero.* Numerals inscribed into the wall of Nana Ghat cave clearly show a number which has been deciphered as 24,400. It is written using special symbols for 20,000, followed by another symbol for 4000 and 400. If these numerals had followed place-value notation it would have been written with only the numerals for 2 and 4 followed by two zeros.

**The Emergence of zero:**

two puzzling features :

1. **The 900 years gap:** None of the Brahmi inscriptions recovered from various parts of India and Nepal, show any sign of place value. Place value suddenly begins to make an appearance sometime around the sixth century, starting with the dates written on copper land-grants (but many of these copper plates have been discovered to be fraudulent). Gradually one begins to see numbers written without special symbols indicating power or rank; the position of numeral itself begins to indicate what power of ten they carried. Zero, initially a dot, begins to make an appearance around this time, the first incontrovertible proof appearing in a Gwalior temple in the year 876.

*There is gap of about 900 years between Brahmi to Nagari place-value numerals.* There are all kinds of wild guesses about what caused this crucial transition, but most of them are just that– guesses. Even those scholars (like Ifrah, to take a prominent example) who firmly and fervently believe that Indians alone invented zero without any outside influence, are unable to offer any clues to how this transition took place, what could have caused it, and how it spread all over the subcontinent and beyond to Southeast Asian lands.

1. The first evidence for zero – as we know it today – comes not from India but from Cambodia, Malaysia and other south-eastern countries.

The following facts are well-established about the emergence of zero in the sub-continent and its cultural sphere in South-East Asia:

* *Sunya-bindu* as a numeral represented initially by a dot begins to differentiate from the metaphysical concept of sunya as void or nothingness sometimes around 600 CE—which is also the time when Brahmi-derived, non-place value numerals begin to give way to place value numerals.
* The earliest surviving and unquestioned evidence of sunya-bindu as a numeral comes not from India, but from Cambodia. It comes from an inscription from a stone pillar which in part says “the Chaka era reached year 605 on the fifth day of the waning moon.” The ‘0’ in 605 is represented by a dot (see ppt). As we know that the Chaka era began in the year 78 A.D., the date of this zero is 683, nearly two centuries *before* the first zero shows up in India. This inscription was documented first by a French scholar George Codes in 1931.The site where the pillar stood was plundered by the Khmer Rouge and no one knew what became of it. It was re-discovered – in a storage shed near the great temple of Angkor Wat – in 2013 by Amir Aczel, an American-Israeli mathematician and a historian of science.

The Cambodian zero is not a fluke. Similar inscriptions with a dot for a zero are found in Sumatra and Banka islands of Indonesia, dated 683 and 686 CE respectively. There are many more inscriptions, too numerous to list here, from other South-East Asian lands, especially the present day Malaysia and Indonesia. The implications of the fact that zero shows up first in South-East Asia before it makes its appearance in India have been fully absorbed by Indian historians, as we will see in the next section.

* The first rock engravings in India that indicate the use of zero in numbers that use decimal place value date back to the second half of the 9th century. The most well-known is the inscription from the Chaturbhuja temple, a rock temple dedicated to Vishnu, near the city of Gwalior (see plate . 7). Inside the temple (which is no longer used for worship), next to the murthi of the deity, there is an inscription dated year 933 in the Vikram calendar (which translates into 876 CE). The inscription is about a gift of a piece of land, measuring 270 x187 hastas, to the temple. This land was to be turned into a flower garden, from which 50 garlands were to be offered to the deity every day.

What makes this inscription a milestone in the history of mathematics is that the numbers 933, 270, and 50 are written in Nagari numerals using place-value and a small empty circle representing zero.

This is the first undisputed evidence of the use of zero in a number found in India.

* Two other pieces of *contested* evidence are still cited as evidence for place value numerals with zero. The first piece of evidence is a set of copper plates bearing inscriptions about land-grants dating from 594 to 972 CE, and they are sometimes offered as evidence that zero and place value were known to us much before the Gwalior inscription. However, the authenticity of the plates has been questioned. The other piece of evidence is the famous Bakshali manuscript found in 1881 in the village called Bakshali in the north-western region in modern-day Peshawar, Pakistan. The partly-rotted birch-bark manuscript contains problems involving basic arithmetic, and clearly uses a dot in place-value numerals. Augustus F. R. Hoernle, the Indian-born Indologist of German descent who first studied the text, dated the work to the 3rd or the 4th century CE. But that date has been questioned by later historians, notably by Takao Hayashi in 1995 who places the mathematics contained in the text to be as late as 7th century. If Hayashi is right—as claimed by a general consensus among scholars—then the earlier date for zero in decimal place value is ruled out.

**So where did zero come from?**

Joseph Needham, the world-renowned historian of Chinese science has suggested that while the circular figure of zero may have been developed in south-east asia or India, the idea of zero originated in the rod numerals in China. He thinks that it is possible that merchants and monks travelling between China and India learned the Chinese method of computation. Indians wrote the numbers of using their own Devanagari numerals, and invented the sunya bindu (the dot) or oval-shaped sunya (the zero as we know it) to represent the empty space, but the idea and the role zero played in numerical computations originated in the Chinese counting boards.

His thesis can explain why we find zero first in Cambodia and South-East Asia and NOT in India. this is what Needham says:

We are free to consider the possibility (or even the probability) that the written zero symbol, the more reliable calculations it permitted really originated **in *the eastern zone of Hindu culture where it met the southern zone of the culture of the Chinese.*** What ideographic stimulus it could have received at that interface? Could it have adopted an encircled vacancy from the empty blanks left for zeros on the Chinese counting boards? The essential point is that the Chinese had possessed, long before the time of time of Sun Tzu Suan Ching (late +3rd century) a fundamentally decimal place-value system. It may be then that the ‘emptiness’ of Taoist mysticism, no less than the “void” of Indian philosophy, contributed to the invention of symbol for sunya, the zero. *It would seem, indeed, that the findings of the first appearance of zero in dated inscriptions on the borderline of the Indian and the Chinese culture-areas can hardly be a coincidence.*