

# Evolution of human understanding of Nature

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Photo Credit: ISRO

The cumulative progress of science has been truly astonishing.

This development did not arise suddenly and is a result of two million years of hard work.

This is the story of that work.

# Important landmarks in early science



- Homo Sapiens (Archaic Humans) ~1,000,000 years ago
- Flaked tools by humans ~500,000 years ago.  
Other early humanoids also made such tools some 2,000,000 years ago)
- **Anatomically modern Homo Sapiens ~200,000 years ago** (behavioral modernity 50,000 years ago).
- Spread across Africa ~ 200,000 years ago.
- Oldest jewellery ~135,000 years ago.
- Fire ~125,000 years ago.
- Formal Language ~100,000 years ago.
- Oldest art on red ochre ~100,000 years ago.
- Oldest man-made bed ~77,000 years ago.



# Tracing Human History Through Genetic Mutations

By examining DNA patterns that are inherited maternally or paternally, scientists can trace human lineages back to the original branches, or sons and daughters, of a genetic Adam and an Eve.

## Europe

### EVE (mtDNA)

The nine European lineages are named H through K, and T through V. One of the lineages, X, diverges to America, but its route is unknown.

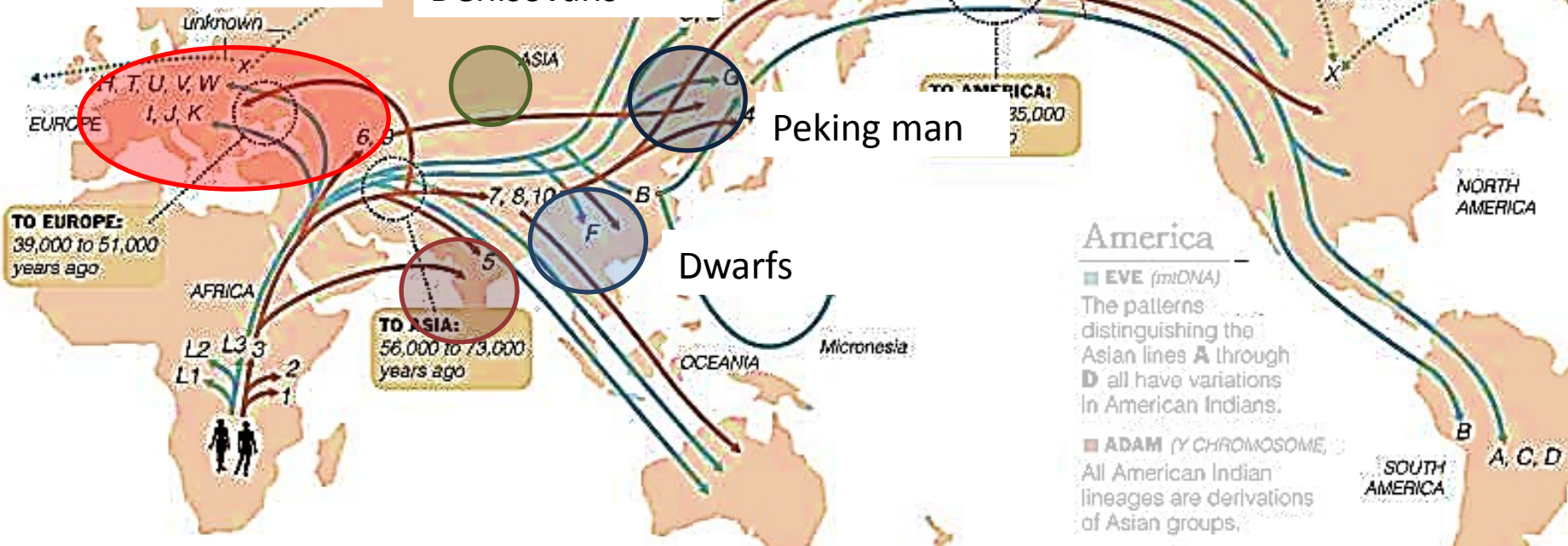
### ADAM (Y CHROMOSOME)

All European lineages are variations of African and Asian branches.

Men and women certainly colonized the world together; the differences between the routes shown reflect differences in genetic information.

Interbred with Neanderthals

Interbred with Denisovans



## Africa

### EVE (mtDNA)

The three African branches are named L1 through L3, and L3 separates into all the other branches.

### ADAM (Y CHROMOSOME)

The three African branches are named 1, 2 and 3, and 3 separates into all the other branches.

## Asia

### EVE (mtDNA)

The six Asian branches are named A through D and F and G.

### ADAM (Y CHROMOSOME)

The seven Asian branches are 4 through 10, and these groups branch off into Oceania, Europe and America.

Sources: Dr. Douglas C. Wallace, Marie T. Lott, Emory University; Dr. Peter A. Underhill, Stanford University; "Genes, Peoples, and Languages," by Dr. Luca Cavalli-Sforza

Steve Duenes/The New York Times

# Later humans

Humans spread to Africa, Asia and Europe before they became behaviourally modern.

There was a rise in creativity from around 40,000 years ago:

- Cave art and *music* (~40,000 years ago) in Spain, Germany and Africa.
- Female figurines (~35,000 year ago) in Germany.
- Invention of pottery (~20,000 years ago) in China

# Time Evolution of Human civilisation on Earth

**Billions (= 1,000 Million) of years**

4.5 billion  
Birth of Earth

3 billion  
Life on Earth

0.25 billion  
Dinosaurs

0.10 billion  
Humans

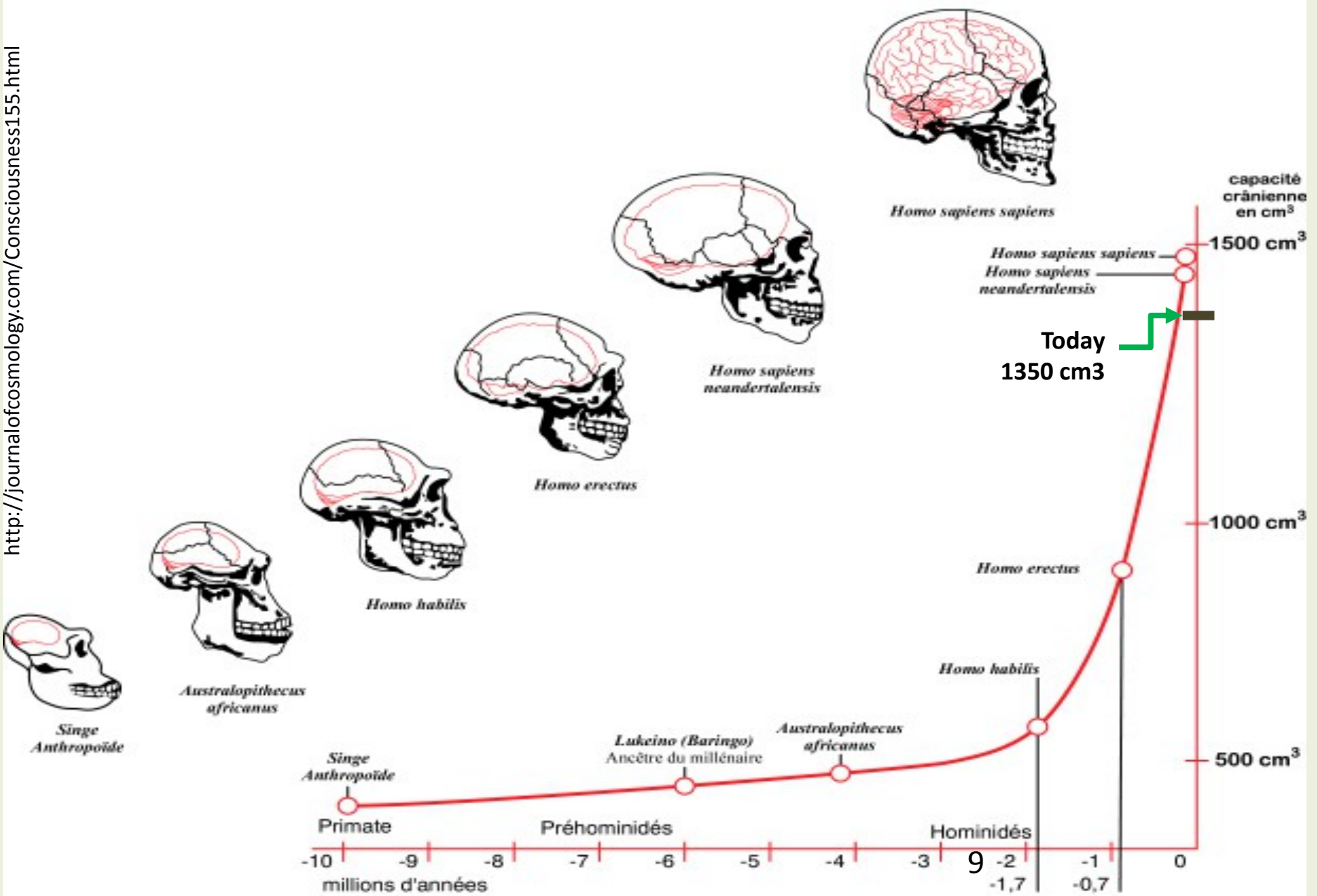
# Recent humans

- Horse was domesticated about 6000 years ago.
- Pyramids were built 4500 year ago.
- First large cities emerge in Harappa 4500 years ago.
- First major religious text appears 3500 years ago.
- Mahabharata 3300 years ago.
- Iron discovered 3300 years ago.
- Greek civilisation 3000 years ago.
- First trans continental kingdom appears 2500 years ago.
- Vikram Samvat begins 2072 years ago (58 BC).
- Gazni invaded India 1000 years ago.
- The European expansion across the globe happens<sup>8</sup> 500 years ago.



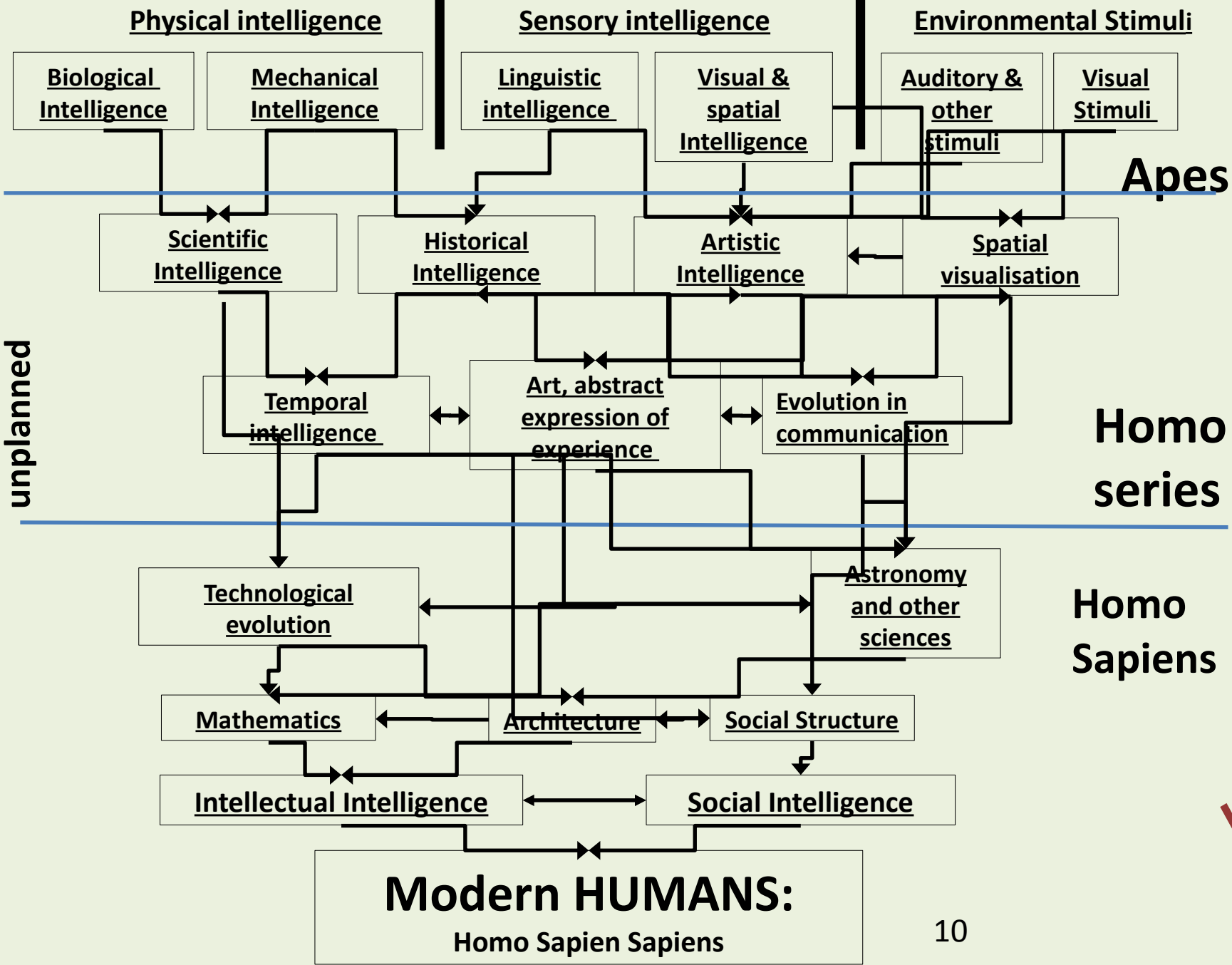
# Evolution of human brain

<http://journalofcosmology.com/Consciousness155.html>



Instinctive and evolutionary/  
unplanned

Formally acquired



Time/ overall growth of intelligence

# Approaches to science

- Ad hoc Approach
- Religious Approach
- The Pragmatic Approach
- The Axiomatic Approach
- The Logic-based Approach

# Ad hoc Approach

- Purely utilitarian.
- No systems are formally studied.
- Systems are built on intuitive feel and experience.

All science begins this way. While this may be called primitive, a significant amount of comprehension is required.

The method is still prevalent in many routine needs at the lower end of low technology.

# Religious Approach

- The universe is governed by a supernatural power.
- Events is based the will of the supernatural being.
- It has serious problems on issues such as free will.

It discourages any analytical studies.

It has moulded the manner of growth of civilisations.

# The Pragmatic Approach:

- Suggests that the working of nature has a regularity and rhythm.
- **Its exact nature was beyond complete comprehension.**
- Any mathematical formulation is an approximation of nature.
- No physical unity lies behind this mathematical models.

It allowed curious minds to take up complex architecture to accurate positional astronomy.

It provided a way around the hold of the religious approach.

# Early sciences

- A lot of early science was driven by work in India.
- Indian contribution is significant and long lasting.
- For almost two thousand years (600 BC to 1600 AD) India was one of the most significant centres of learning. Its partners were the Chinese.
- It was preceded by Mesopotamia/ Samaria.
- It was followed by Arabs and more recently by the Europeans.

# What Indians were good at – 1

## Early Period (prior to 1000 BC)

- Harappan civilisation 7000 BC to 1700 BC): Its underlying knowledge system must have been very complex and highly evolved.
  
- The level of standardisation manifested itself in terms of:
  - 1.Characteristic written materials and seals
  - 2.Beads and other jewellery
  - 3.Standardised Brick Sizes in the ratio of 1 x 2 x 4
  - 4.Indoor water closets and water management system
  - 5.Planned towns with citadels, platforms and podiums, specific burial patterns
  - 6.Standardised Weights
  - 7.Black or red painted pottery



Harappans had multiple urban centres – with careful, orthogonal town planning.



# Other achievements of the period

- Sulba Sutra: Written in 1000 BC it mentions Pythagoras theorem, 500 years before Pythagoras. This is in reference to making *Havan Kunds*.
- Number system: A counting system based on location based value of numbers. Large numbers based on powers of 10 appear in Vedic period itself. Formal representation comes much later.

# What Indians were good at – 2

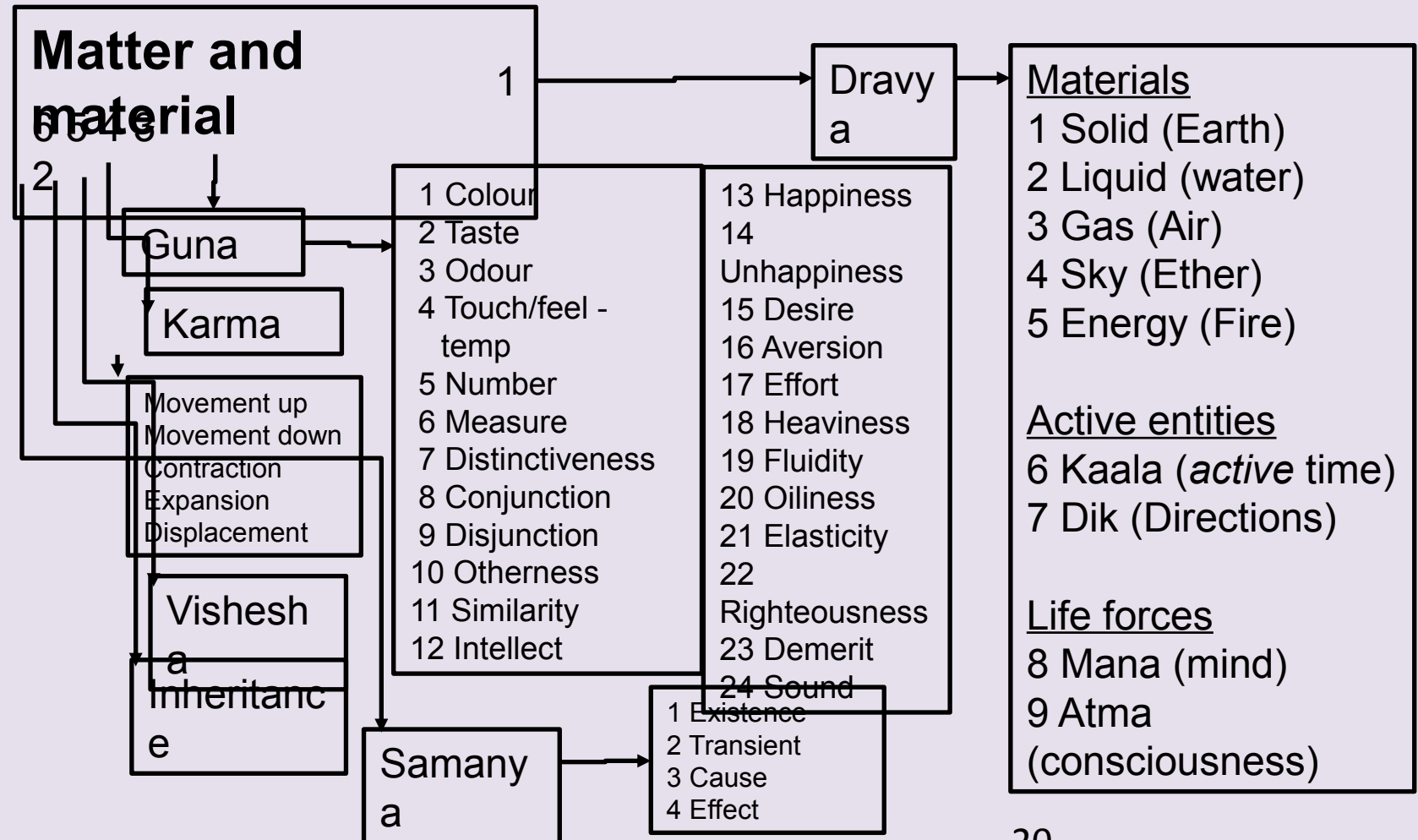
## The Golden period (1000 BC to 200 AD)

- Nyaya and Vaisheshika system – the first genuine, secular text book of science (600 BC).
  - *Nyaya* investigates laws and governance of the universe.
  - *Vaisheshika* is concerned with the nature, sources and limits of knowledge.
- Yoga and Sankhya first text book of medicine (600



# Vaisheshika view of the universe

Vaisheshika and Nyaya system is an early attempt to put together a secular world view about the working of nature. It creates the framework to understand both, the *animate and inanimate world*.




# What Indians were good at – 3

## **Siddhantic Period (500 AD to 1600 AD).**

- Formulation of astronomical problems in mathematics and invention of trigonometry.
- Kerala School of advanced mathematics.
- Temple architecture.

## **Modern period.**

- Architecture of a lot of structures including Taj Mahal.
- Tipu Sultan's rockets.
- And other achievements too numerous to list. 

# Short comings -1

- All matter behaves according to their nature (*prakruti swabhav*).
- Description of nature reached a plateau soon.
- It remained an intellectual pursuit of pure form.
- **Student of science avoided direct experimental studies.**
- Building Harappan cities to Taj Mahal which would have needed an understanding of the relevant sciences but that did not lead further.<sup>22</sup>

# Short comings - 2

- Easy living conditions discouraged studies of terrestrial world.
- **Four major fields of science – mechanics, thermodynamics and electromagnetism and structure of matter were never explored.**
- While there was a general idea of relation between disease and other life forms, absence of microscopes meant that several fields were left out *even though glass had been known to them.*

# Over-claiming

- It is fashionable today to make irrational and exaggerated claims of our past achievements.
- Some of the claims include:
  - Quantum mechanics (uncertainty relation and more)
  - Vimana and interplanetary travel (to Mars, no less)
  - Genetic engineering (including gender changes)
  - Trans animal exchange of organs (head and brain, no less)



# This is a dangerous trend

- Such claims without a demonstrable capability to achieve something of this magnitude is dangerous.
- It gives the Nation a bad name and makes us a laughing stock.

# Attitude of ultra loyalists

The usual arguments of people making such claims are:

- You were not present at that time.
- There are discussions of Ganesha to Shikhandi.
- You are underestimating this genius of our Rishis.
- Since you are educated in western style, you are a slave of their ideology and are not patriotic enough.
- You speak technical nonsense and no one can understand you, so you must be wrong!

# Some examples of evolution of scientific ideas

- Quantum mechanics arose after we had mastered Electromagnetism and Thermodynamics.
- In merging the two we encountered the problem of stability of atom and laws of Quantum Mechanics were discovered.
- For aeroplane we needed to understand:
  - dynamics of air, wind and Bernoulli's principle
  - We needed industrial revolution to make internal combustion engine.

# Some more examples

- for genetic engineering, we need to understand:
  - Life at molecular level
  - Centrality of carbon in life
  - Double helical structure of life's molecules
  - Microscopy etc. to understand and manipulate molecules
  - Isolate these cells in extremely clean and low temperature environment and then study and manipulate them

# Most importantly

To achieve this we needed

- Powerful mathematical tools.
- Electricity.
- Clean environment and appropriate structures.
- Large scientific manpower and an elaborate system of education.
- The arguments that talk about our past, happily mix time sequences and insist that future knowledge was available in the past!

Returning to the main story

# The Axiomatic Approach:

- Assumed that nature worked in strictly logical way of mimicking the ideal.
- These laws were universal and amenable to mathematical representation.
- All laws were universal and true for all times and locations.
- The Greeks came to this while trying to distinguish between *mythos* and *axioms* – myths and truths!

# Foundations for axiomatic approach

- Axiomatic method needed long traditions of meticulous observations that predated the Renaissance period.
- Without deep universal understanding of the working nature, the axiomatic method would have failed.
- This led from Gallilio's astronomy – Newtonian mechanics – thermodynamics – electromagnetics – particle physics etc.
- It was responsible for phenomenal increase in technologies.



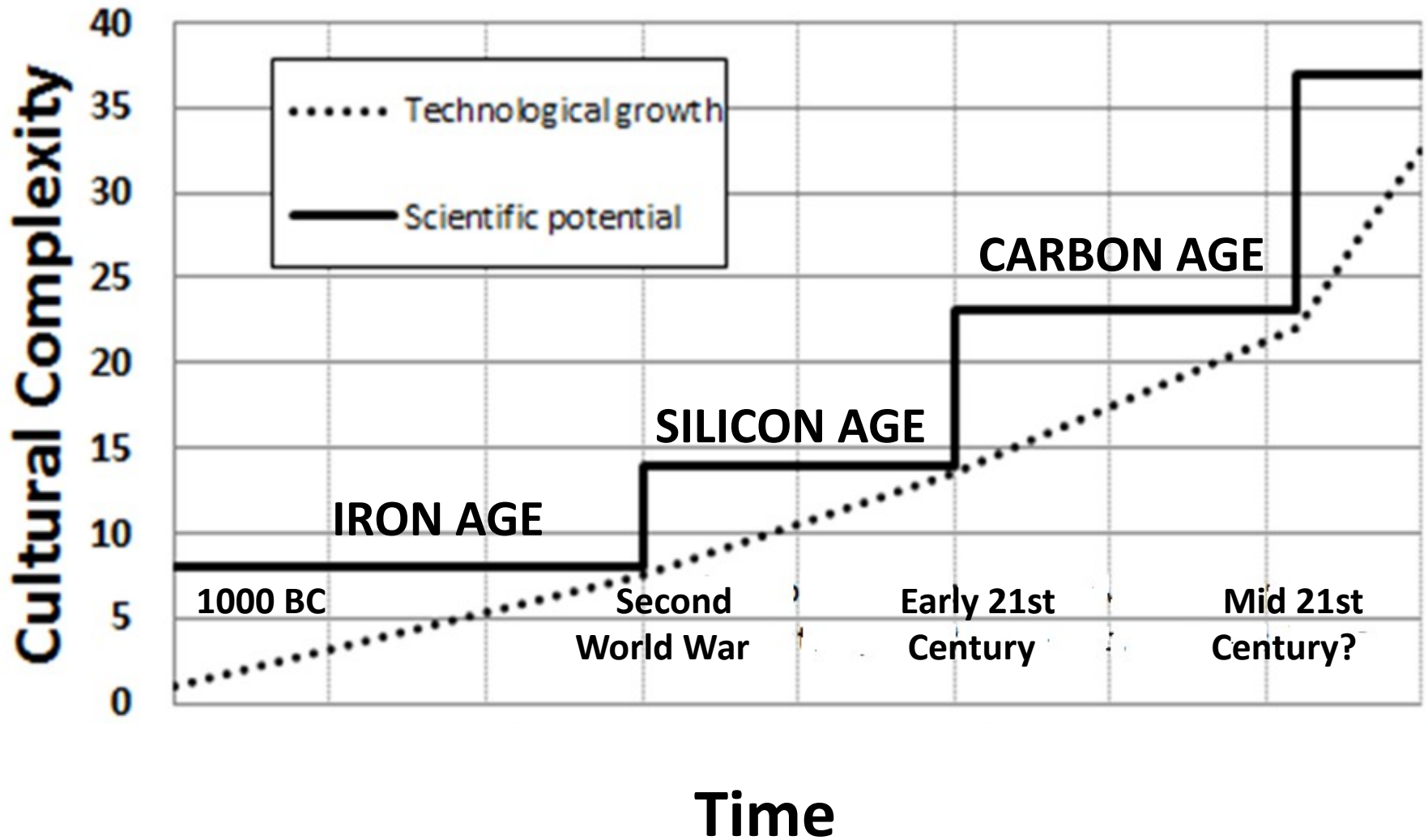
# Modern Science

- It began in Europe in the Renaissance period.
- It absorbed the results of the pragmatic approach.
- It revived these traditions with vigour even as they heavily borrowed from logic-based and pragmatic approach of the Asians.

# Successes of modern science

- Europe made quick progress in our understanding of nature and our capability to manipulate it.
- With a commitment of experimentation for validating their axioms, they soon discovered thermodynamics and electromagnetism – fields that had been completely missed by the pragmatics.

## Potential and real growth of a Civilisation



# Future of Science

- However, this approach is reaching its limits.
- **Limits of formalisation:** Godel's Incompleteness theorem that states that in any axiomatic system will have statements, that even though true, will not be provable within this system.
- **Complexity of system:** All realistic systems are complex system and not amenable to the kind of simplification crucial to mathematical description.
- Experimentation, simulation and 'true to the best of our knowledge' approach will dominate.

# Limits of axiomatic approach

- Study increasing complex systems requires understanding interplay of several different forces.
- For example, chemistry is a study of Van der Waals forces. But studying it in increasingly complex environment, forces simplification and generalisation.
- While it is built on the axioms made for isolated systems, it attempts to study nature *in situ* with all its complexities.
- Most work on science today is done through direct experimentation or simulations.

# The Logic-based Approach

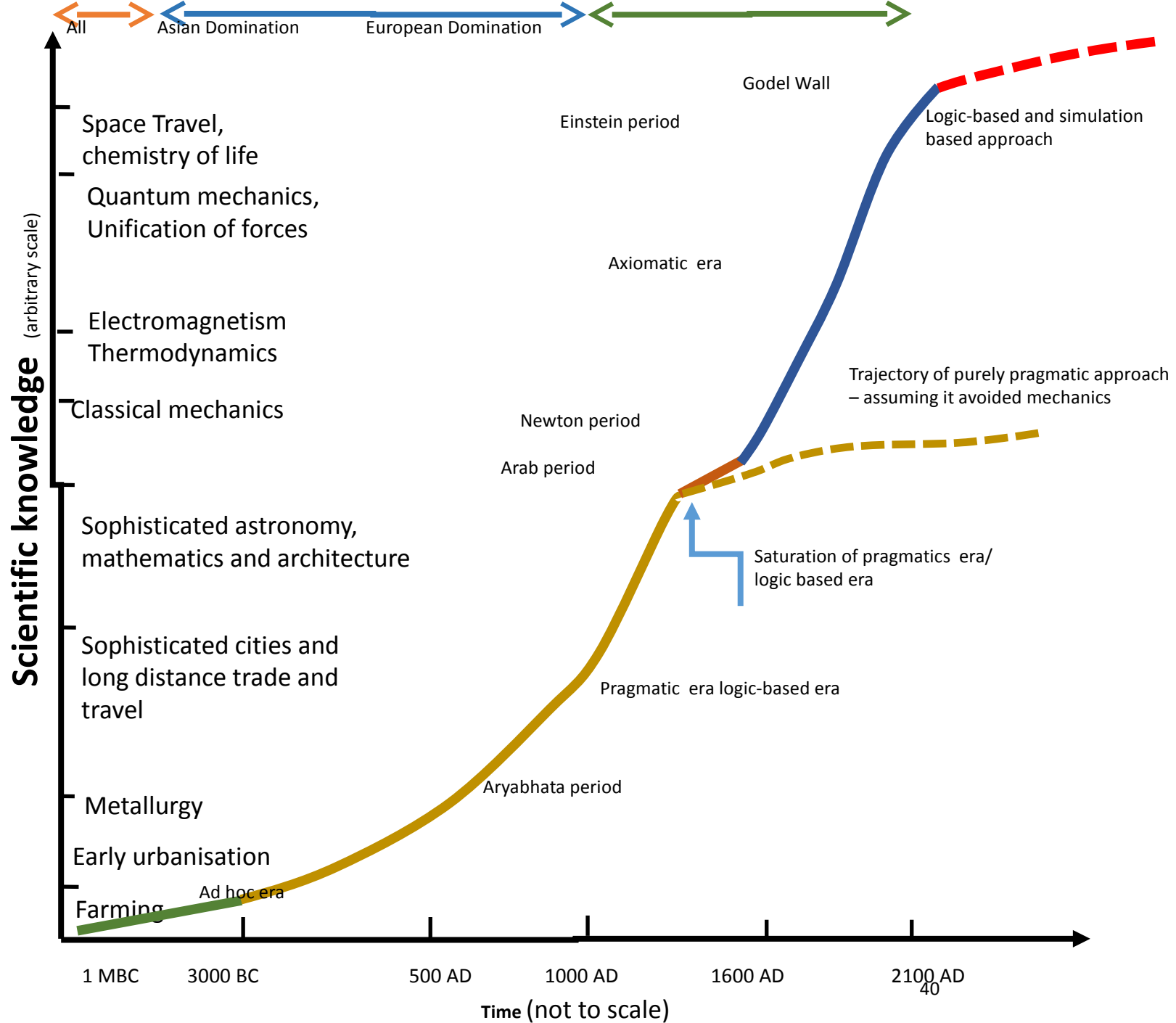
- The working of nature has underlying axioms which are best described in the language of mathematics.
- Nature obeys all its laws all the time and under all conditions.
- Given the complexity of nature, realistic situations cannot be isolated and application of several constraints simultaneously is not amenable to pure mathematical analysis.
- Hence search for pure mathematical formulations may not be the best way to describe them **in view of the inherent complexity**.
- Hence it is impossible to prove 'facts' and the best we can do is to state that something seems true based on all available experimental (and simulation data). This remains valid until improved analysis can be done.

This approach runs parallel to the Axiomatic Approach and has provided analogy for mathematical representation *but replaces formal proofs*

# Human capabilities

- This is also a reflection of the limits of human brain.
- Designed to survive in the wild – to eat, not be eaten and reproduce – human senses are hierarchical with visual sense having the highest priority.
- This predisposes the brain to visualise.
- This visualisation is also mixed with a degree of anticipation and causality.

• Any visualisation eventually becomes more logic





End

# The road ahead

- Future science will be a merged field where axioms will not be proven but will be shown to be true beyond reasonable doubt.
- The validity of these descriptions of the governing principle of nature will have to be demonstrated by non-falsifiability within the reach of computer modelling and experimental testing.
- A concept will be true because it cannot be falsified under any situation we can think of and simulate.

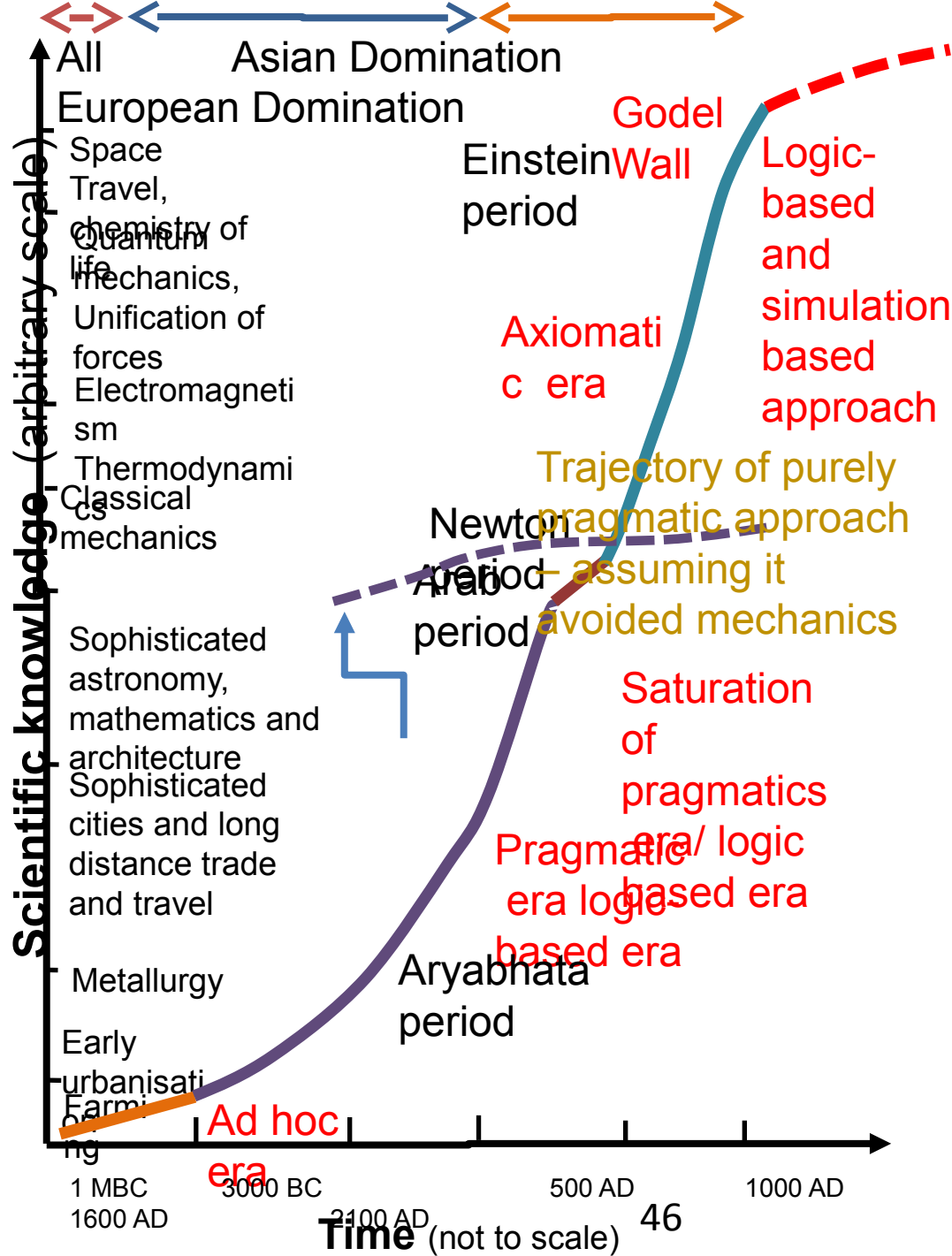
# Future methods of science

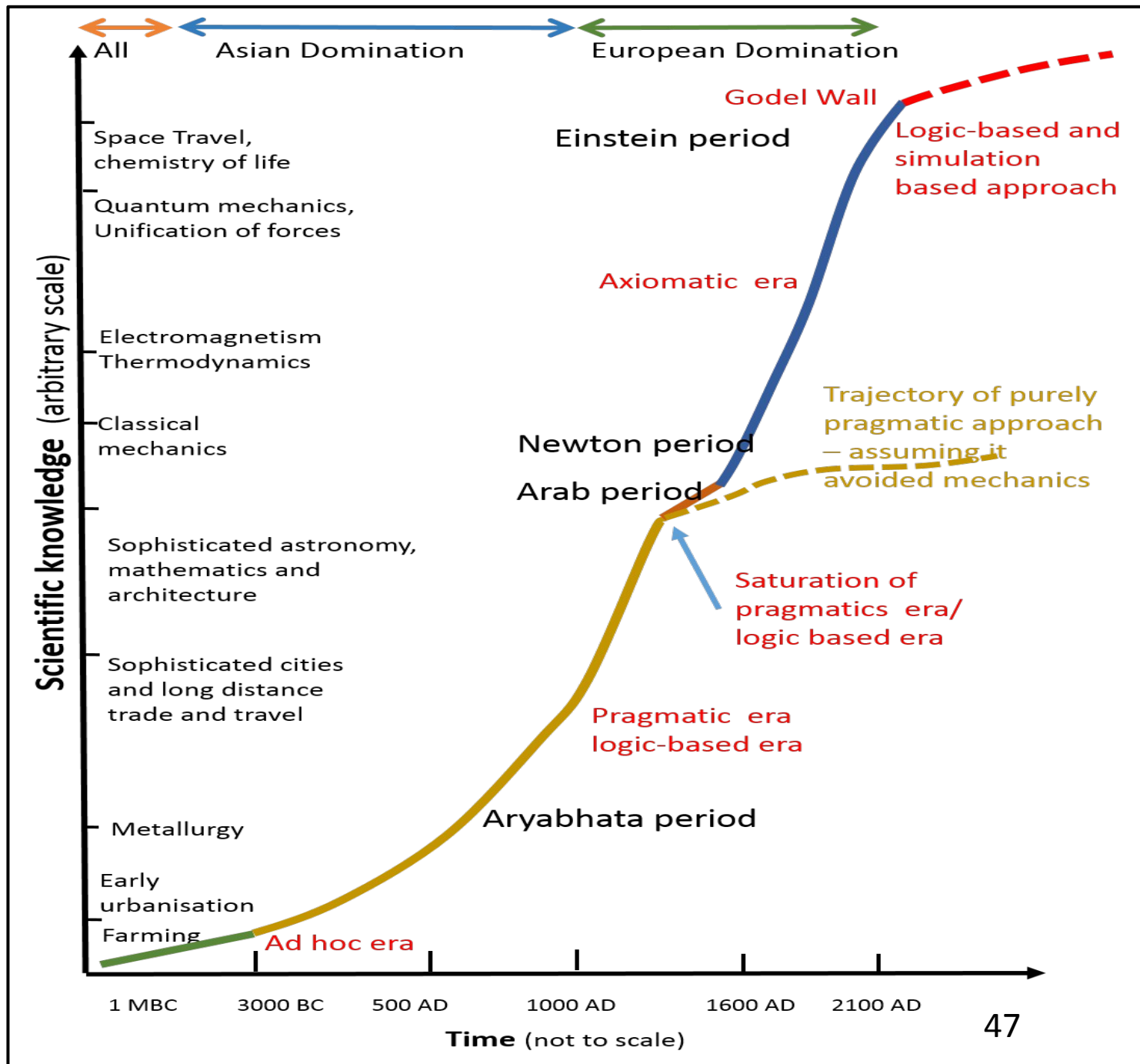
- The future of science is increasingly logic-based and pragmatic.
- Technologies will work entirely with logic-based technology.
- The basic argument is that nature obeys a set of rules and they can be combined into a machine which in some ways makes our life more comfortable or interesting.
- Hence the exponential increase in knowledge may have been triggered by axiomatic approach, it is only a transient state in the long march of humans

# The Godel Wall and future science

- The future of science therefore is drifting away from purely axiomatic approach as various subjects reach the Godel Wall.
- One can argue whether the Godel wall is a limitation of human mind or whether the complex systems (with their intrinsic tendency to be chaotic) are difficult to define axiomatically.
- String Theory, for example claims legitimacy based more on a logical approach than axiomatic proof.
- Cosmology is another field where the Godel Wall arising from lack of knowledge of acceptable axioms – has resulted in logical approach to science.

N o	Approach	Period of dominance	Characteristics	Approach to observation of smoke on the mountain*	Major Achievements
1	<b>Ad hoc Approach</b>	2 millennium BC to 5000 BC	Made objects from instinctive understanding of nature.	There is smoke on the mountain – avoid the region	Early technologies from stone tools to travel.
2	<b>Religious Approach</b>	2000 BC to 1000 AD	Accumulation of ad hoc knowledge into technologies for secure living and worship	There is a divine smoke on the mountain – worship it	Stabilisation of society.
3	<b>Pragmatic Approach</b>	3000 BC to 1600 AD and continuing to date but at a lower scale	Nature is assumed to work in a logical and consistent way that can be analysed. But any such knowledge is good only for the situation in which it is applied.	There is smoke so there must be fire on the mountain	Clarity and mathematical precision in prediction.
4	<b>Axiomatic Approach</b>	1600 AD onwards	Nature's working is consistent and universal and nature obeys all its rules under all conditions and has no exceptions.	The smoke on the mountain implies that: 1) There is dry inflammable material on the mountain. 2) There is a source of heat that heated this material to the temperature where is caught fire.	Development of new technologies, simplified description of nature.
5	<b>Logic- based Approach</b>	500 AD onwards but less prominent than Axiomatic approach	Working of nature is logical and consistent that extends to common rules which work well. However, there is only partial verifiability of generalised universal laws.	There is smoke so there is fire, implying that there is inflammable material on the mountain.	Providing intellectual explanation for the working of the laws of nature.



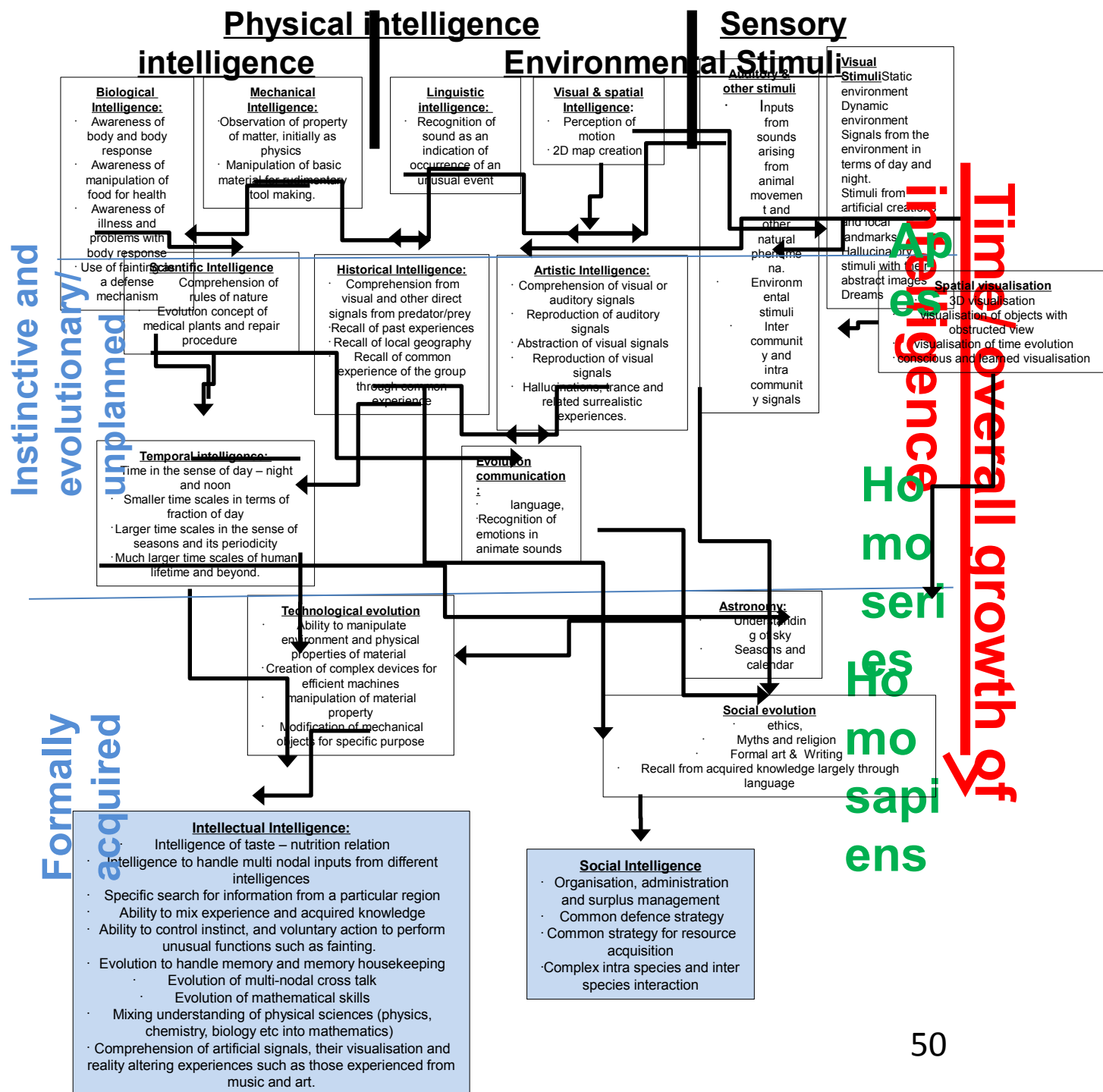


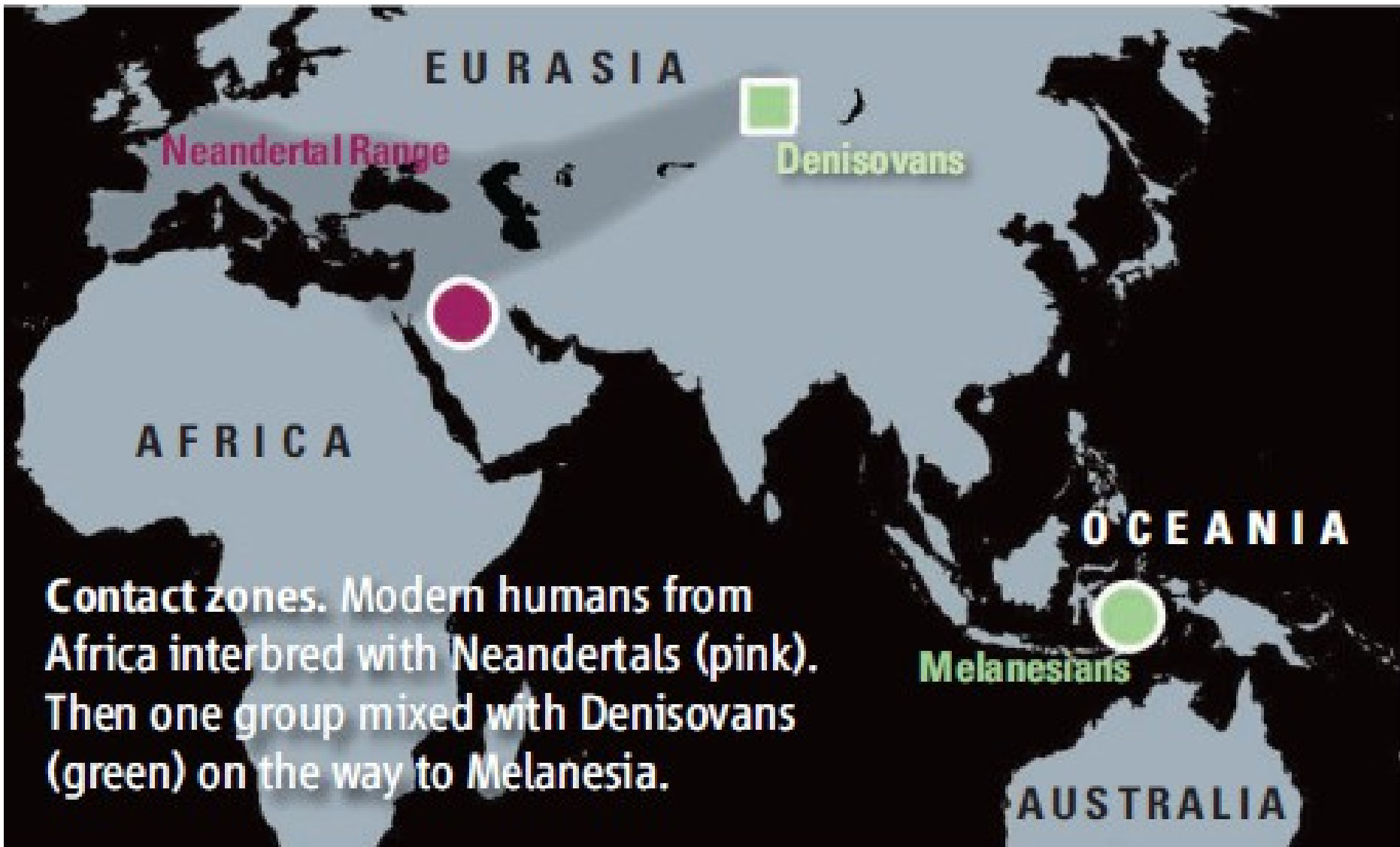
# Evolution of human intellect

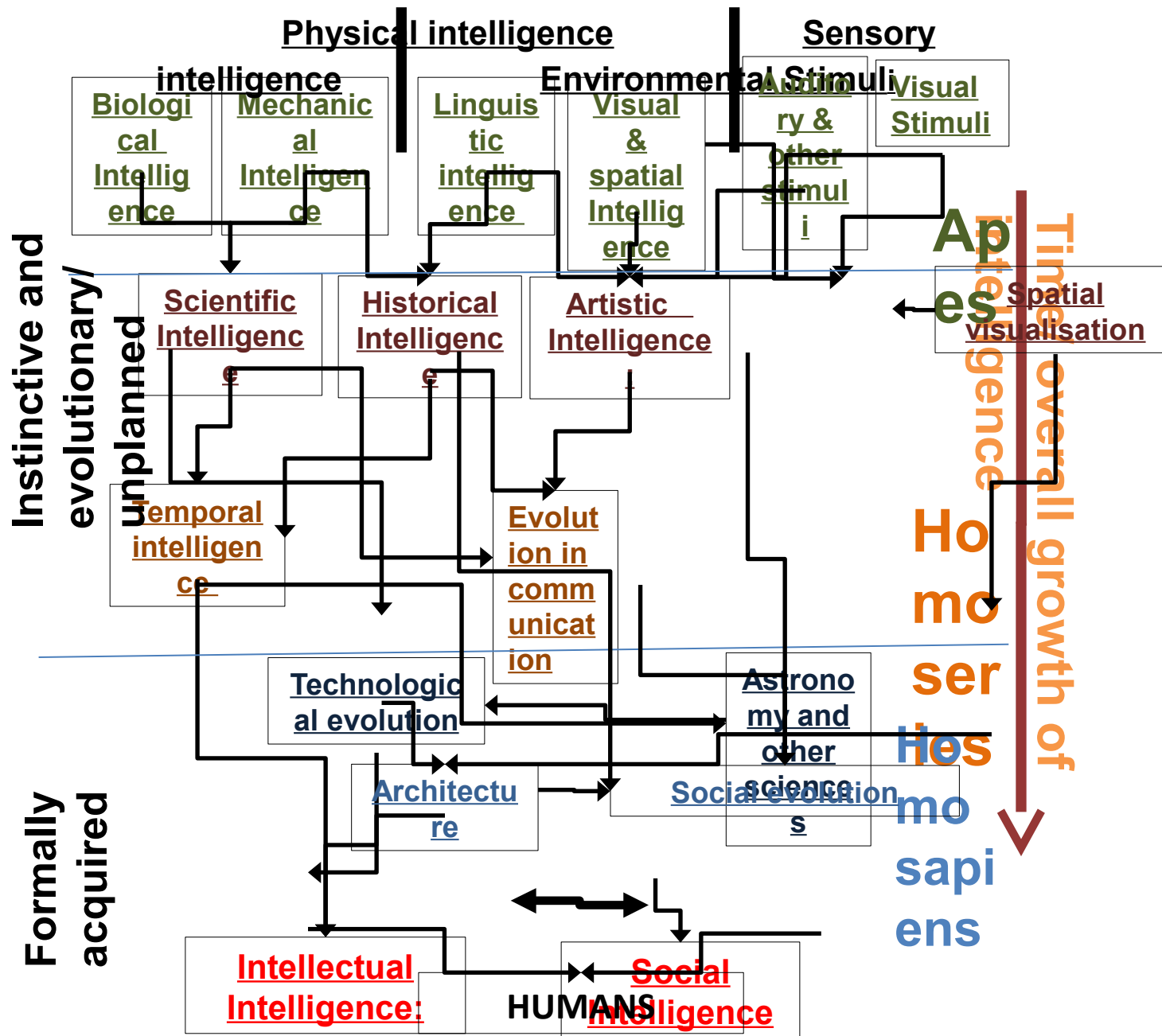
- Humans before migration already had a tradition of:
  - tool making
  - Cave painting
  - religious ideaswhen they set out from Africa.
- Hence these are similar in all cultures.
- Astronomy and mathematics are different and clearly have parallel roots.



Community	Period since settlement	Level of astronomy										Cumulative score	References
	(period since settlement when study is reported)	Name for Directions	Know constellations: <5 = 0.3; 5-10=0.6; >10=1	Astronomy in daily life	Myths of seasons	Philosophical myths	Astrology	Eclipses	Planets	Lunar mansions	Observatories		
Relative weight		1	10	5	8	10	10	10	10	10	10		
Gonds	1000	1	0.6	0.5	1	1						27.5	Vahia and Halkare (2013)
Kolams	500	1	0.6	0.5	1		0.5	1				32.5	Vahia et al. (2014)
Banjaras	100	1	0.3		1							12	Vahia et al. (2014)
Sumerians	3000	1	1	0.5	1	1	1	1	1		0.5	66.5	
Greeks	1000	1	0.3	0.5	1	1	1	1			0.5	49.5	
Chinese (early period)	3000	1	0.3	1	1	1	1	1	1	0.5	0.5	67	
Egyptians	1000	1	0.3	1	1	1	1					37	
Greko Roman	3000	1	1	1	1	1	1	1	1		0.5	69	Taken from Sumerians
Mayan	4000	1	1	1	1	1	1	1	1	1	1	84	
Rig Vedic	1500	1	0.6	1	1	1		1		1	49	50	Sastry (1984)
Late Vedic	2000	1	1	1		1		1	1	1		56	Iyengar (2013)







# Time Evolution of Human civilisation on Earth

## BILLIONS OF YEARS

4.5 billion Birth of Earth      3 billion Life on Earth      0.25 billion Dinosaurs      0.60 billion Mammals      0.06 billion H Sapiens

## MILLIONS OF YEARS

1 million Homo Sapiens on Earth      0.5 million Flaked tools      0.6 million Anatomically Modern humans

$\div 100$

## HUNDREDS OF THOUSANDS OF YEARS

2 lakh Modern human      1.35 lakh Jewellery      1.25 lakh Fire      1 lakh Language, art      0.77 lakh Making beds      0.7 lakh Animal traps      0.6 lakh Migration

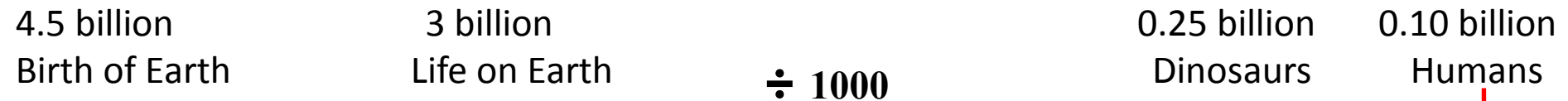
$\div 10$

## TENS OF THOUSANDS OF YEARS

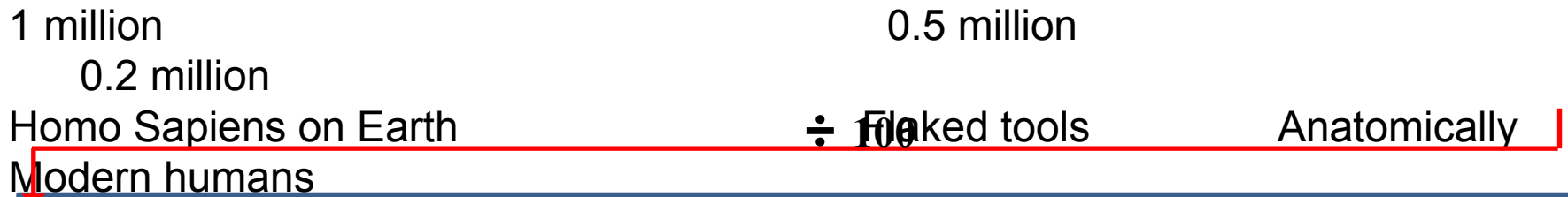
50 k years Behaviourally      40 k Cave      35 k Female      20 k Pottery      10 k Farming      8 k Writing      7 k Metal

# Time Evolution of Human civilisation on Earth

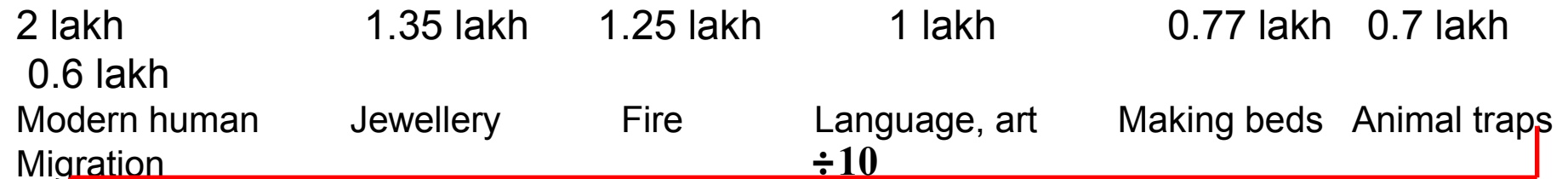
**Billions (= 1,000 Million) of years**



**Millions (= 10 lakh) of years**

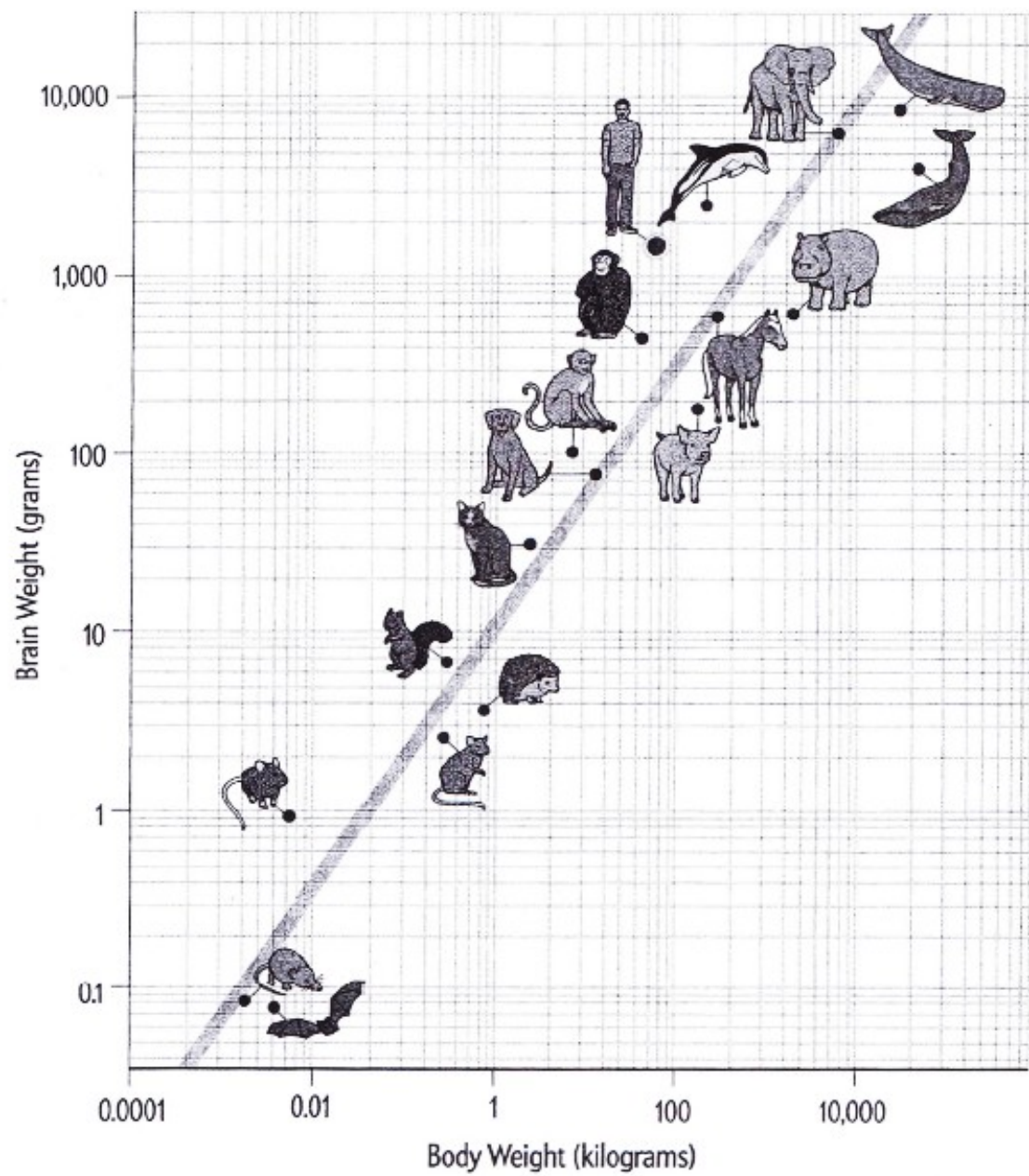


**Lakhs (= 100 thousand) of years**

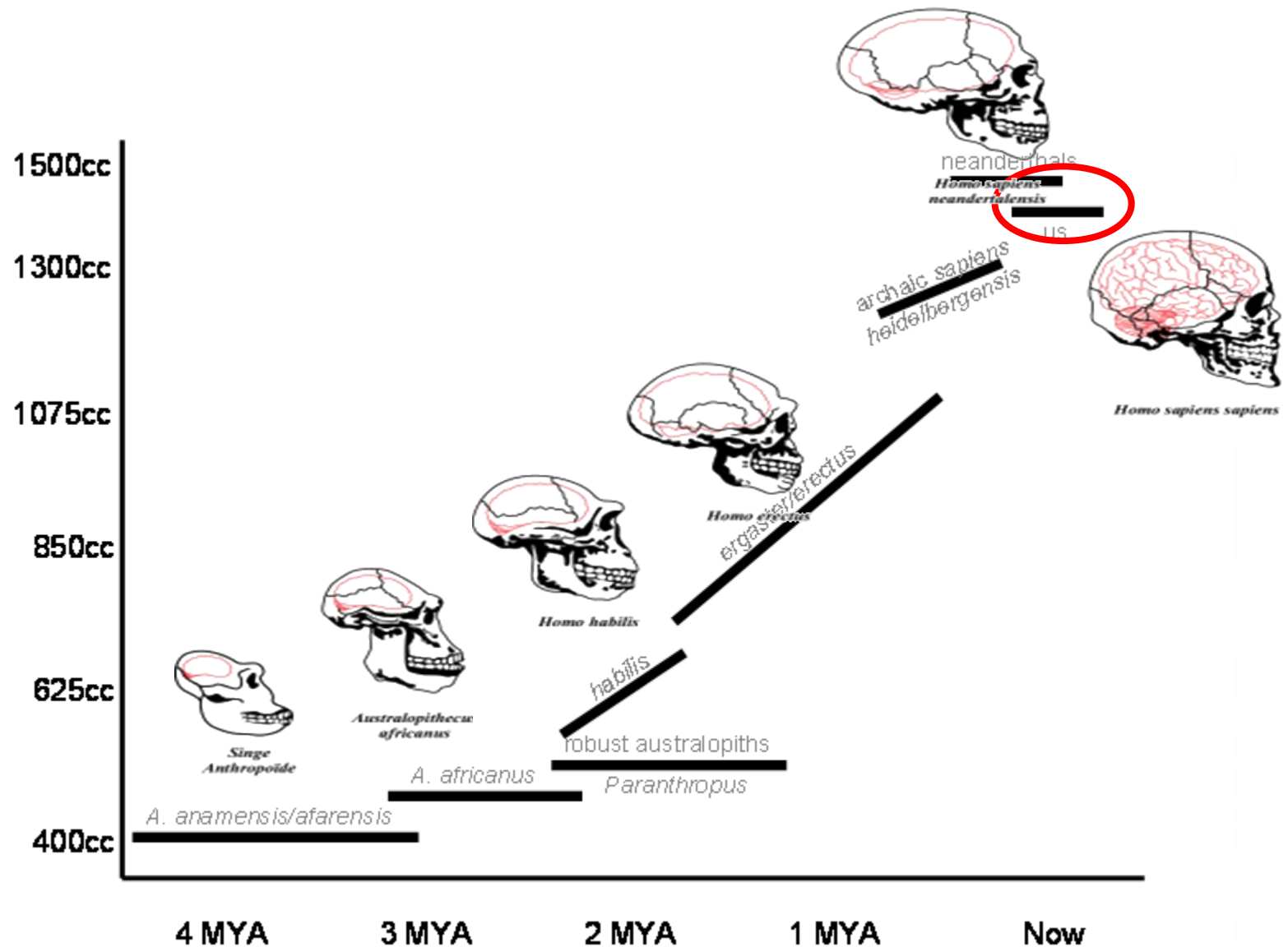


**Tens of Thousands of years**





# Subtle aspects of evolution of brain





# Astronomy and questions of Human mind

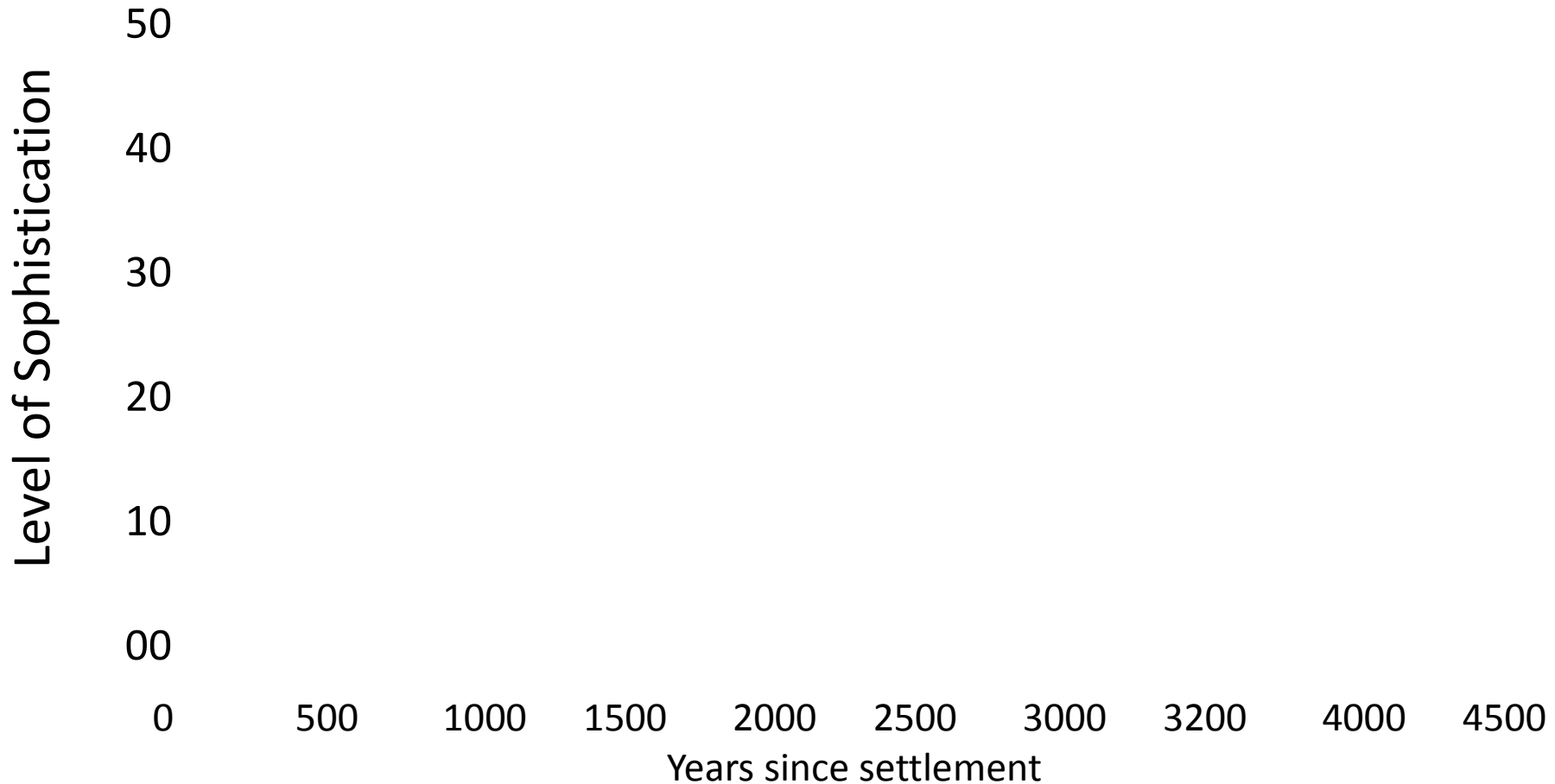
- ***Astronomy arises very late in human history.***
- Mother Goddess arise 35,000 years ago but astronomical records are 15,000 years ago.
- Astronomy is not so easy to realise. It needs perception of:
  - The existence of sky and the vertical dimension beyond the landscape.
  - Relationship between the weather and the Sunrise point.
  - Creation of stable abstract patterns in the sky and understand its movements and rhythm

# Astronomical progress of astronomy

- However, once discovered, astronomy becomes central to the civilisations:
  - Mother earth is now joined by father sky,
  - Dead are connected to heavens,
  - Sun dials and Observatories are built,
  - Calendars created,
  - Mythologies are created,
  - Cosmogonical ideas about humans and their place in the universe arises.

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Rig Vedic	1500	1	0.6	1	1	1	-	1		1	-	50
Late Vedic	2000	1	1	1		1	-	1	1	1	-	56
India 500 AD	3500	1	1	1	1	1	1	1	1	1	0.5	79
Early UK	1000	1	0.6	1	1		1	1			1	50

# Development of astronomy and its relation to period of settlement

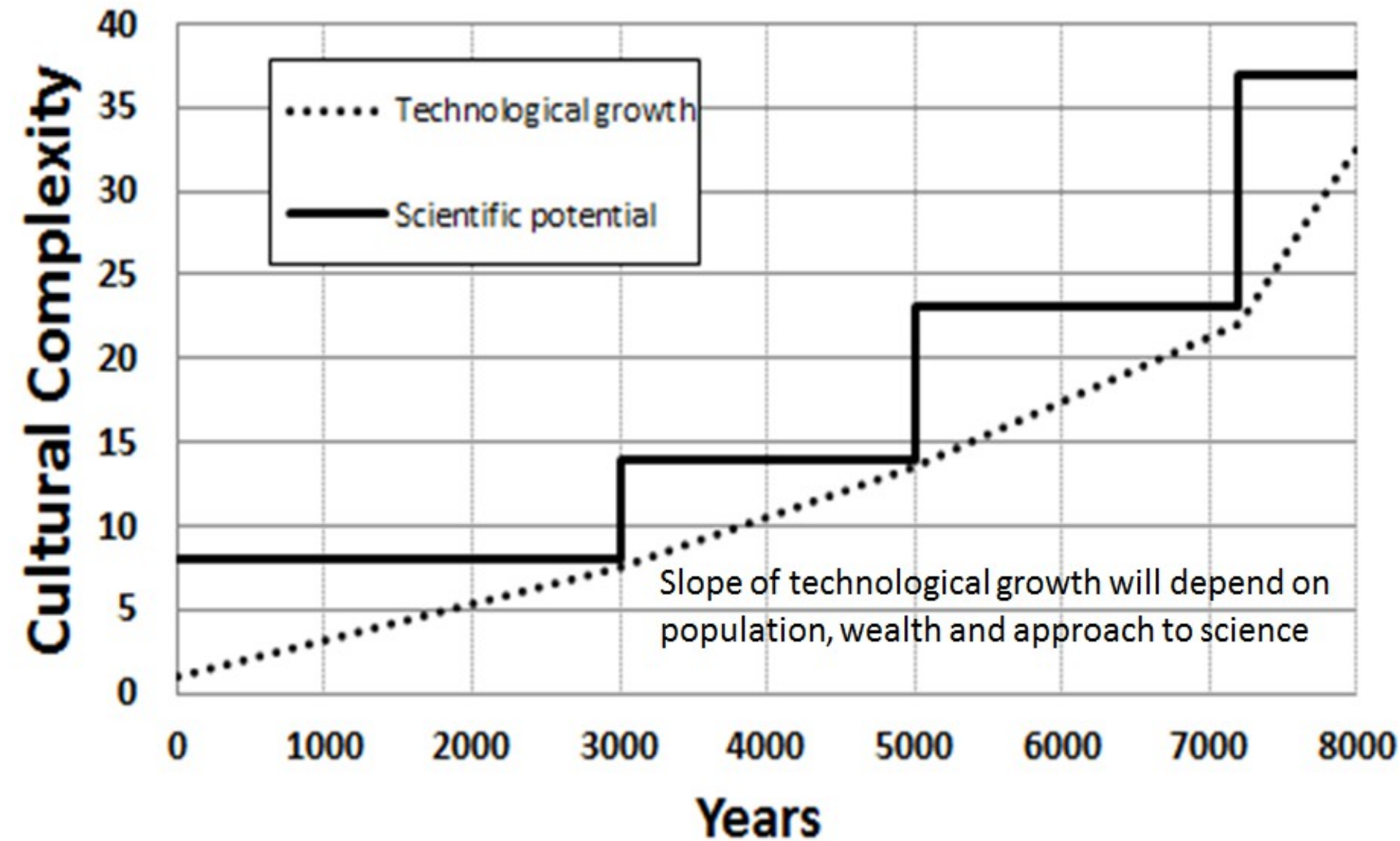


# Archaic and modern human skulls

## black background is archaic



## Potential and real growth of a Civilisation



# There is no need for this.

- **There is no need to do this.**
- What ancient Indians achieved in their time was extraordinary for their time.
- A lot of work is trendsetting and of highest quality.
- So why make false claims when real ones are good enough?