A brief history of the ideas that made civilizations

Preface - Is the society just a sum of the individuals?

Consider a glass of water at room temperature where its molecules in motion collide against each other and the walls of the glass perpetually. Large changes in velocities and positions of the interacting molecules due to these collisions, cancel out almost perfectly leaving the water as a *whole* unchanged. There is a complementary principle of nature that describes changes of the whole: very small modifications in the interacting individual elements can result in large changes in the collective behaviour of the whole. A well-known manifestation of this natural principle that humans have been exploiting for millennia, are the properties of metal alloys. For example, steel manifests very different properties from iron due to a small fraction of carbon atoms added (typically less than 1% in weight) in a heat-and-cool process. A resulting change in the bulk material, gives us the tensile strength of steel that can be more than 10 times higher than that of iron. Of course, understanding this large distinction in their behaviour in terms of an iron and a carbon atom, is not possible. The whole is greater than the sum of its parts!

Today's evolving human societies encounter this above duality as well, even as the individual is more complex and variable in behaviour compared to an atom but limited by birth and death. The *average* individuals of two societies may have fundamentally little to distinguish themselves from each other as humans on a relative scale, but the collective response of each society to a given situation can indeed vary much around the world, as well in time. So, what makes up the difference between the whole (society) and the sum of the parts (individuals) here? It is the set of ideas that are reinforced and strongly manifest in each society as a collective. Note that a person can only have few conscious ideas that vary purely by their own analysis and objective experiments. Many ideas develop by inheritance and reflection of information from others in our societies and are collectively driven and subject to constraints set by geography and natural laws. Minor distortions in individuals' ideas affect the reflections of our images from each other, and in turn some behaviours may be enlarged only in the collective but are not readily apparent as individuals.

Collective effects of the small deviations in individuals also compound over time resulting in very different outcomes for the evolving societies. Hence, a relatively small set of ideas can well-distinguish a society among its peers, if not each of its individuals. We may also step back further in time to infer that the difference in the intrinsic biological capacity between a human and an evolutionary cousin like a chimpanzee, could be *relatively* small compared to the large differences in the accumulated capabilities of their corresponding societies today. That additional capacity of language in humans is a key component in intensifying and sensitizing the human interactions to form large, continuously learning, capable human societies that are very different from the animal kingdom. The more connected world we have today due to modern communication devices does not necessarily alter this duality, and it rather makes this principle more relevant to the emerging global society. Note that most collective goals set today have either critical or existential impacts for the individual. The above-described natural principle of collective effects then demands that we indeed distinguish the trees (individuals) and the woods (societies) in discussions on our challenges and relevant solutions. We may also see the evolving human societies as living entities in a longer

time scale, and this is not purely metaphorical, as they may indeed satisfy some essential conditions associated with living beings.

Writing human history as a flow of connected events representing changing ideas, but anchored in a profound understanding of the present:

History of humans may be best described in a nutshell by the slow variation of their ideas manifest as a collective, which is also indispensable for a vision into our future. Also to be kept in mind is that history is a qualitative description of our collectives using sparse anecdotal evidence, as the relevant quantitative data of individuals is mostly unavailable. Typically, a description of a society of the past is in terms of its relative achievements (*best*) in the materials used and the progress in military, scientific and architectural spheres. The notion of averaging over all people and events is very relevant but extremely challenging in history. This is especially so in sociocultural issues, where a society and its people can simultaneously manifest both enlightened and egalitarian principles on one side, and misconceptions and prejudice on the other. Thus, evidence of the evils (*worst*) of the society have also been used in sketching the past.

One could also argue that a critical and broad understanding of the present world as an *objective* and *quantitative* reference point, is an absolute prerequisite for the modern historian in extrapolating the available sparse evidence and rewinding to the distant past. This expectation is often belied, and we do find popular historiography that is clearly misaligned with the events and the plainly evident characteristics of today's world. This is because the history of science, economics and religion is often made subservient to political history, as the latter is the easiest to infer and align as a sequence of past wars and rulers converging to the present.† Thus, military conquests and imperialism over another is typically recalled positively as indirect evidence of scientific and cultural advancements. An unwitting presumption also implicit here is that societies and their rulers always needed to plunder another's resources to gain economic superiority. This distortion in our memories may be the root of today's expansionism, mistrust and conflicts among countries. Further, medieval and modern history of different geographical areas are strongly related to each other due to the increased mobility of humans and their mutual impacts. This renders the isolated historical examination of a geographical area inadequate for deeper insights. So, let's take a very brief look at the global human history as the evolution of a few fundamental *ideas* relevant to science, socioeconomics, and religion. ††

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† The historiography of arguably India's greatest emperor Ashoka, and the contradictory (North Indian and Sri Lankan) records available to us, is a case in point. The Kalinga war fought eight years after his coronation killed 100,000 soldiers on the battlefield and more elsewhere, about 2300 years ago. This may have moved him to widely propagate the largely non-religious principles of Dhamma/Dharma (non-violence among others), even into Greece after the death of Emperor Alexander, taking a title for himself as *Devanampiya Piyadasi* (Beloved of the lord who is humane). He was known to be violent in disposition and may have taken up Buddhism about five years before the war. These facts are contradicted in the simplistic popular history where he supposedly converts to Buddhism due to the consequences of the war and so becomes a propagator of peace.

†† References are not listed in this concise overview article, as authentic sources like archives, papers and books for each of the numerous historical data points mentioned can be searched for and found online. The precise numbers and dates become relatively immaterial in this overview of changing ideas and are hence neglected wherever appropriate. Note that some of the evolving historical inferences can be subject to debate and future studies.

Agricultural revolution, early civilizations, and the emergence of religion, writing, and numbers (beginning about 12,000 years ago):

A relatively sudden increase in average temperatures brought an end to the ice age and may have led to a significant rise of sea levels pushing coastlines inwards by as much as a thousand kilometres. In Greenland, average temperatures rose by around 10 °C within 500 years, and 20 °C overall in a 3000-year period, melting its ice in significant fractions. Loss of hunting grounds due to rise in sea level and increase in local density of humans, and new vegetation in barren lands due to changing weather patterns, may have provided a renewed impetus to observe and grow plants for human and animal consumption. This may have induced humans to evolve from hunting and foraging in small groups, into more permanent settlements supported by agriculture and domestication of animals. The quality of dietary intake may have reduced for a period in some places, and diseases may have affected the population due to dense settlements containing animals and poorly conserved grains, but the overall complexity of society continued to increase over years. The closer human interactions may have also fostered more complex thinking and resulted in use of composite tools for harvesting, written alphabets for recording different types of grains, and numbers for counting animals.

A related evolutionary question is the shrinkage of human brain volume that seems to have been continuing since a hundred thousand years ago. While we may not have sufficient samples to trace the rates of shrinkages over the years, the probable causes may be of most relevance, and there is indication that it may have accelerated during this age. Unlike hunting and foraging, life in human settlements did not require to process large spatial and image information. Simultaneously, division of labour and the use of language may have invited an increase of energy-intensive computing tasks over plain memory tasks. This may have triggered an evolution of brain towards optimal computing where radiation of waste heat prefers a smaller brain. This shrinkage is observed even in the brains of domesticated animals compared to their wild counterparts, though one should be careful in extending this correlation all the way to the small brains of ants, where the fungal farming ants do have larger brains than their foraging counterparts. The recent computing revolution has made it possible for a significant fraction of human brain functions to be duplicated in electronic devices, and we should closely note the potential consequences on our brains. In fact, a reduction of the average generational IQ over the previous one was reported recently for the first time since such evaluations were done. Whether it’s a language or our brains, the maxim ‘either use it or lose it’ may hold! On the other hand, our understanding of the operations of the human brain is still primitive and it is also believed that unlike in man-made computing systems, our memory and thoughts are given by configurations/arrangements of signals of a distributed brain-body system. Thus, it may be too early to be conclusive on the reduction in human brain-volume over the years.

While these early human settlements increased food security to an extent, the varying weather patterns and diseases did result in humans searching for higher powers manifest in the natural elements such as the sun, wind, fire, mountains and rivers, along with their dead ancestors. These early forms of beliefs called *animism* exist even today in isolated tribal communities. The natural and supernatural elements were later given specific human or animal forms and characters establishing *polytheism* i.e. the worship of many gods with varying beliefs. The increasing urbanization and complexity of thought later graduated polytheism into two fundamentally variant ideas of God that exist today i.e. *Monotheism* and *Pantheism*. Narrowing itself from polytheism to a

single *human centric* god, a monotheistic religion is exclusive in its idea with a negation of other gods and belief systems. On the other hand, the idea of pantheism broadened and subsumed polytheism, in considering the entire universe and its living beings as the embodiments of the higher power. For example, one of the earliest monotheistic religions called Yahwism may have emerged from ancient polytheism more than three thousand years ago, through brief interludes of monolatry or henotheism i.e. worship of a preferred god but without the negation of others. On the other hand, a large part of Hinduism would graduate from the polytheistic worship of the elements to a pantheistic philosophy of a universe with implicit consciousness, while the individual was free to practice polytheism and monolatry in their own preferred form. These two fundamentally distinct ideas of the supreme i.e. monotheism and pantheism, would leave deep but very different imprints on the history of humans, and other aspects such as wildlife conservation and biodiversity.

The earliest agricultural civilizations rose on the basins of river systems, and they include Mesopotamian (Euphrates-Tigris), Egyptian (Nile), Indian (Indus-Saraswati), and Chinese (Yellow River) among others. It is not yet clear where the first civilization may have risen, but the areas to be first studied systematically have been in Mesopotamia guided by its biblical relevance. Carnelian beads and seals discovered points to trade between the Mesopotamian and Indian civilizations in the early times, which included spices, textiles, and precious metals, and this trade may have included the Egyptian civilization as well. Standardized weights used in trade have been found to differ in both the units and their shapes across the East European (spools and parallelopiped tiles), West Asian (ducks) and Indian (cubes) civilizations. The standard cubes along with a well-developed measurement system of length units as small as a few millimetres, indicates that an early understanding of the concept of (volumetric mass) density may have existed in the Indian system. Its perforated gold coins (*Nishka*) may be the earliest known currency used at least four thousand years ago. Rolling logs used to move materials had graduated into solid wheels during the period, and it later morphed into the spoked *potter's* wheel that was used in multiple ways. The large pyramids of the Egyptian civilization built more than four thousand years ago are an enduring example of the early advances in integrating river and land transport of materials using water engineering. Well-designed streets, washing areas, and drainage systems in the brick-built cities of the Indus-Saraswati civilization seem remarkably modern for their times, with a surprising non-existence of weapons and large temples. It is now considered as the earliest and the most well-developed bronze-age civilization. The increasing urbanization of humans during the period was also made possible in part by the metallurgy of copper, brass and bronze. While copper was soft and unsuited for hard tools, its mixture with the metal tin produced a hard and ductile bronze that could be shaped into sharper tools and other precious artefacts. Melting copper in its powdered form was possible in clay kilns that may have been used earlier in pottery, fuelled by fresh wood, charcoal, dung and olive pits among others, depending on the local availability. Both metals tin and copper are not abundant, and this may have limited the otherwise possible wider use of these tools.

Second urbanization: the iron age and study of mechanics, city-states and collective intelligence, and the divergence of religions (beginning about 3500 years ago):

Iron melts at a significantly higher temperature around 1500 °C compared to copper at around 1000 °C and tin at 250 °C, where these melting temperatures marginally change with the impurities. It implied that the metallurgy of iron followed after extensive experimentation in making

bronze tools, even though iron ore is more abundant on earth. The iron ore was heated to temperatures up to 1250 °C in the clay kilns to remove impurities and soften the metal, which then needed extensive forging to make useful tools. While carbon steel also resulted in such processes used in the iron age beginning 3500 years ago, the significant development of a high-grade alloy called wootz steel in southern India and Sri Lanka about 2600 years ago made light weapons possible as it can hold strong sharp edges. This alloy was traded to many parts of the world, and a few hundred years later the only ask of the Greek emperor Alexander from the defeated king Porus of western India may have been the wootz steel he had. The process included the use of a crucible (large container) with sand, glass, ash and other fluxes, heated with blasts of natural wind of the monsoons, possibly resulting in banded carbides and carbon nanotubes in the material. This steel was also later produced in West Asia under the trademark of Damascus (Syria) steel in the medieval times more than a thousand years later, and efforts to reproduce this steel began in the 19th century Europe under the Royal School of Mines among others. Another notable development was the open-hearth furnace used by the Haya tribe in Tanzania to produce steel about 2000 years ago, later in Catalan (Spain) in the 8th century AD, which was then reinvented by Carl Siemens in the 19th century Germany to mass-produce steel. Many large rust-free iron constructs of the Hindu temples built more than a thousand years ago also indicate early advancements in metallurgy, contrary to popular perceptions on historical technological developments.

With iron tools more widely usable in agriculture and new currency available as punched coins of gold, silver, and brass, extensive agriculture of fertile lands and the trade in produce, textiles, and artefacts became more viable in this age. With weapons made of iron also available for large standing armies to protect the newfound wealth, new city states emerged from the once human settlements. In northern India for example, large human settlements (Janapadas) and some even integrated as kingdoms, had rose around 4000 years ago subsequent to the collapse of the earlier Indus valley civilization likely due to a climate anomaly. They later aggregated into 16 city-states (Mahajanapadas) around 2700 years ago with two of these city-states following a democratic form of governance. The oldest known university was established in Takshashila (Taxila) followed by another in Nalanda a few hundred years later, which had students from as far as Greece, China and Syria. These independent city-states mirrored the city-states of the Greeks and Rome in some ways, and they may have survived for about 400 years until the emergence of larger empires i.e. Mauryan and Roman empires respectively. Social complexity had to rise in these early cities due to the urbanization with a clear division of labour, and the now possible accumulation of individual wealth due to currency used widely. This may have been the undesirable cost incurred for the increased collective intelligence of the society that now significantly outweighed any individual. Megasthenes, the Greek ambassador to the early Mauryan empire has been quoted on some notable differences in India, like the surprising absence of slavery, the exalted social status of farmers, and the considerate treatment of flora and fauna. Nevertheless, a *Dasa* system of temporary servitude based on indebtedness may have existed in ancient India. Later, a hereditary social stratification of the caste system would originate from its occupational (Varna) system seven hundred years after Megasthenes and become entrenched under the later imperial and colonial rules. Other civilizations of this period in the Americas (like the Olmec and Maya) and in southern India may not have yet been fully explored today, and recent studies portend significant discoveries. While the former is noted for its expansive structures built, the latter in southern India show an early development of iron tools with a continuous human presence since the prehistoric (megalithic) period.

Food and security may have stopped being immediate concerns for many in these city-states, presenting the luxury of indulging in literature, scientific and philosophical questions for the interested. The Mesopotamian legal code of *Hammurabi* in its Babylonian sub-civilization, and the extensive *Vedic* hymns on multiple facets of life in the Indus-Saraswati civilization, are among the few known such works originating before the city-states emerged. On the other hand, literary works like the *Odyssey* (Greek), *Shijing* (Chinese), and *Thirukkural* (Tamil) are only a few of the many known classics of the later city-states, with intricate epics like *Ramayana* and *Mahabharata* (Sanskrit) being ten times longer than the rest. For many citizens of these early cities, achieving a higher social status would then slowly emerge as a new purpose of the relatively secure human life. The social stratification would also usher in a host of supremacies and prejudices among humans that continue to the day. Ideas of religious, racial, national, caste and class supremacies would become entrenched, and lead to untold human suffering in the next two thousand years. Religious and national supremacy in particular, continue to be legitimized in popular opinion even today.

Recall that polytheism had narrowed into *monotheism* in some parts of the world, while it had broadened into *pantheism* in other parts of the world. At the beginning of this age the dominant representative of monotheism is a new religion of Judaism that evolved from Yahwism, and pantheism was represented by Hinduism respectively. Later, two new monotheistic religions Christianity and Islam emerge from the lands of Judaism, and similarly, two other pantheistic religions Buddhism and Jainism emerge from the lands of Hinduism. During the spread of Buddhism to China, Daoism takes form with similar pantheistic ideas and they would coexist well. The monotheistic religions would devour most of animism and polytheism in the world (like Zoroastrianism/Parsi in Persia), but the pantheistic religions would survive into the future precariously. Monotheistic ideas may have initially helped cohesion in an urbanizing world but did so at the cost of fostering supremacy and insecurity over their need to negate other beliefs. Note that even a seemingly indifferent religious proclamation declaring idol worship a grave sin, could turn half of the world into sinners and thousands of ancient structures into targets for destruction. The traumatic relationship among the three monotheistic religions would also heavily contrast that among the three pantheistic religions over the next two thousand years. Note that the latter religions largely separated political power from the clergy and indulge other beliefs in the collective, notwithstanding aberrations of the individual. Dispassionate voices continue to affirm that all humans are equal and all ideas are not, even when none are perfect.

Political thought in the newly urbanizing world was not far behind, and *Analects* from the ideas of Confucius and others, *Arthasashtra* by Kautilya and others, and *Republic* by Plato, are classics of the period which comment on the relationship between the individual and the society and its governance. The independent developments of what is today known as the *Pythagoras theorem* in different civilizations is a prime example of human curiosity and conscience driving us towards the same inviolable laws and truth. This theorem relating the two smaller sides and the largest side of a right triangle with a 90° angle, was useful in building solid structures like religious altars and found in the Mesopotamian (Babylonian) civilization in the form of empirically observed triplets. Whereas the earliest known mathematical statement of this theorem is in *Shulba Sutras* (Sanskrit) at least 2800 years ago, and the earliest known proof in *Zhoubi Suanjing* (Chinese). Detailed records on human health are represented by the Babylonian *Sakikkū* (diagnosis of divine senders) about 3000 years ago, and the *Yoga Sutras* (yoga) and *Sushruta Samhita* (medicine and surgical procedures) written in Sanskrit about 2500 years ago. The perfect set of rules framed by Pāṇini at

this time to generate not just sentences but also words in Sanskrit from its few roots, makes it the only known zero-error language machine, and hence he is known today as the father of linguistics.

The Greeks were fascinated by the geometry and the mechanics of the new tools possible in the iron age, with texts such as *Metrica* and *Pneumatica* written by Hero of Alexandria. This followed Aristotle's earlier incorrect propositions on mechanics and astronomy 2300 years ago, when astronomer philosopher Kaṇāda in India described the motion of a body in three laws which in hindsight are similar to the laws used today. While the earlier bronze-age classification of the basic states of nature into earth (solid), water (liquid), air (gas), space (vacuum) and fire (plasma) related closely to today's physics-based classification of states of matter, he now also introduced the atomistic theory of materials in India. The atomistic theory proposed earlier in Greece would unfortunately lay buried in the west for more than two thousand years due to Aristotle's opposition. The Egyptian water wheels used in irrigation may have had an efficiency more than 20% in converting the mechanical energy of the water flow to useful work, and so may the earliest cotton gins used in India. The *kallanai* dam built on the river Cauvery in India about 1900 years ago during Hero's time in Alexandria, stands in use even today. The Chinese texts *Suàn shù shū* (Writings on Reckoning) and the *Nine Chapters on the Mathematical Art* written around the same time describes the developments in geometry including a high accuracy of the constant π. Indians were more absorbed in the celestial mechanics of astronomical objects, presumably influenced by their pantheistic philosophy. Indian astronomy motivated the development of the modern number systems and trigonometry due to the precision required in predictions of celestial motion, which was thus different from the purely geometrical approach elsewhere. Functions such as sines, cosines, versines were computed and tabulated along with precise values of constant π, by mathematicians like Aryabhata and his followers such as Bhaskara-I and Brahmagupta about 1500 years ago,† in addition to the invaluable works using the decimal place value system of numbers including zero, and the development of algebra. Continuing from Indian mathematician Bhaskara-II of the 12th century AD who confirmed that division of a number by zero results in infinity (in addition to his other seminal works on algebra and astronomy), the Madhava's school of mathematics on the southwestern coast of India discovered infinitesimal calculus and distinguished its branches of differential and integral calculus in the 14th century, and even used infinite series expansions of trigonometric functions that are today called Taylor's and McLauren series.†† But the east was now regressing, and the west was rising in this sphere of developing great ideas, both driven by a peculiar combination of political, religious and climatic history and the related transfer of ideas from the east to the west.

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† The decimal place value system and mathematical operations using zero should be distinguished from using a symbol for an empty set which may have been common even a few thousand years earlier in many parts of the world. The first such known use of today's place value system in computation was in *Lokavibhāga* (division of the universe) in the 5th century AD written about 50 years before Aryabhata's known composition *Aryabhatiyam*. Indian astronomers are known to have described numbers in place values of digits with powers of ten increasing from left to right, even four hundred years earlier. In addition to Aryabhata's large contributions to the foundations of mathematics, note that he considered the earth and moon as spheres with the former rotating on its axis, and was even able to predict the size of shadows of the earth on the moon along with proposing heliocentric models. The accuracies of his calculations were surpassed more than 1300 years later in the 19th century. The relative significance of his scientific contributions may surpass the great contributions of Newton and thus may be the greatest ever by any known individual.

†† The location of Madhava's school on the active routes of spice trade also begs the fascinating question of whether this work could have inspired the later work in Europe, where Christian theologian and mathematician Isaac Barrow

(Isaac Newton’s mentor) and astronomer mathematician James Gregory at the University of Cambridge are credited with the discovery of infinitesimal calculus a few hundred years later. While there was more than a century of intense arguments over whether the English mathematician Newton or the German mathematician Leibniz first discovered the early forms of calculus, note that many other talented European mathematicians subsequently developed calculus to a form that is used today.

While the Roman empire was polytheistic with even international gods such as the Buddha being crafted in its temple of Isis in Egypt about 1900 years ago, emperor Constantine's legal recognition of Christianity later in the 4th century may have paved the way for the commoners to convert. When the German tribes among others ended the Roman empire in the 5th century, most of the erstwhile western Roman empire was not only split into many tribes and their kingdoms, but also into many Christian denominations such as Roman Catholics, Arians and Nicenes among others, with their bishop councils playing a crucial political role in the fractured society. After the advent of Islam in the 7th century, large parts of Europe's eastern and Iberian-peninsular regions were quickly conquered by the early 8th century in a holy jihad by Islamic caliphates. Conversion to Islam was probably the only way to escape slavery in parts of eastern Europe and the peninsula, and it was adhered to in large numbers. The northern and western parts of Europe without notable economic activity were considered by the Islamic rule as a source of slaves and raw materials, where the cold climatic conditions seemed unwelcoming. But in the second half of the 10th century a Medieval Climate Anomaly (MCA) brought in warmer temperatures, longer summers and agricultural prosperity and population growth for western Europe, while on the contrary causing droughts in northern Africa, West Asia, and the Americas. This global climatic phenomenon over a period of about 300 years driven by a combination of solar activity, volcanic activity and ocean circulations may have led to large scale political changes, as we understand it now after independent climatological studies beginning in Europe more than fifty years ago, later in the Americas, and then West Asia in recent decades. The increased migration from West Asia into Europe due to the climatic stress may also have launched the crusades, where the now stronger Christians in western Europe declared religious wars to reclaim their holy lands from Islamic rule. In practice, these religious wars may have ended only in the 20th century and may still be relevant in terms of the current crises in the holy lands of Palestine, and the larger global climatic crises emerging.

In the Indian subcontinent, the relatively mixed effects of this (MCA) climate anomaly on the summer monsoons may have resulted in a marginal increase of overall agricultural output. The prevailing hardship in West Asia due to the droughts and religious wars thus encouraged a new wave of attacks on India from its west, driven by both economic and religious motivations. This instability further may have impacted the silk routes of trade which had never been fully safe in practice, whereas the sea routes through India connecting both Rome and China were probably more reliable. A consequential event was the seizure of Mongol traders and their goods by the rulers of northern Persia (Khwarazm) and the subsequent murder of the Mongol envoys sent for mediation. It triggered the invasion of central and western Asia by a Mongol ruler widely known by his areligious title Chinggis Khan or Genghis Khan, and his later conquests of China and parts of Russia with the aid of the feared Mongol cavalry. This made the Mongol the largest ever contiguous empire in the world, also setting up the Yuan dynasty rule of China. These impacts of the Medieval Climate Anomaly were followed by a more local anomaly in Europe from the 15th to 19th century, called the Little Ice Age (LIA), resulting in agricultural and economic hardship and ending in a

general crisis of violence and plague epidemics in the 17th century. This then played a significant role in the European colonization of the world and the industrial revolution.

Military revolution and the global expansions of slave trade and political economics (beginning about 500 years ago):

The key Chinese inventions of gunpowder, paper, movable printing, and navigation-compass under the Song dynasty were probably brought to Europe through the silk routes that flourished after the Mongol invasions of West Asia, and the decline of sea trade through India. Similarly, the knowledge of making colourful fabrics out of cotton passed to Europe from India. Though gun powder was introduced to Europe in the 13th century AD, the 15th century invention of a matchlock i.e. a gun with a wick to ignite the powder, made widespread military use of chemical energy possible. This resulted in drastic changes in not just warfare, but economics, banking and the political landscape. The value of skilled soldiers became negligible, as mercenaries could be trained quickly in the use of guns. On the other hand, arms became expensive making its trade lucrative and the required financial resources a primary factor in standing armies, leading to a centralization of rule by strongly coupling trade with warfare. The East India Companies of the Dutch, and then the British, are well-known examples. Note that religion in the form of evangelism had already been coupled to trade in the early European exploration for new lands during the Little Ice Age. Stand-off weapons like guns also allowed enslavement and control of a large number of human beings, resulting in a self-reinforcing trade cycle of arms in the exchange for slaves, especially in African regimes. The countries that did seek economic gain through colonization, in turn developed an enlarged class of nobility and bankers, deepening the political control of the elite despite the apparent democratic forms of governance that may emerge.

Large producers of goods driven by agrarian wealth from abundant sunlight and arable land were fresh targets of this new paradigm of military and economic warfare that started in the 16th century; India being a prime example with a third of the world's GDP. *New* lands in the Americas and elsewhere that Europe was unaware of, were all thus imagined having *Indians* living there. In large parts of India though, the Islamic imperial rulers had already brought in a wider stringent slavery of enemy soldiers and tax defaulters, with the citizens of other religions subjected to special taxes. For example, Timur of Mongol-Persian origins with a Turk army took about a hundred thousand slaves during a short advance to Delhi in the late 14th century, and later brutally massacred them all overnight, in a repeat of his massacres in Isfahan (Iran), Herat (Afghanistan) and Tulamba (Pakistan) among others. Note that these imperial conquests required manpower, and slaves from India were taken as far as central Asia. The biographies of these imperial rulers written by their own courtiers are among the most reliable sources, though this official language of the court such as Turkish or Persian could be foreign to an Indian historian.

The newfound colonial warfare and economics beginning in the 16th century made this slavery more endemic, with Indians enslaved and traded to far off lands by sea in millions over centuries. In addition to the threat of slavery, the interest of the earlier imperial and the later colonial rulers in having a fractured hierarchical society to rule over, promoted the caste divisions of the local Hindu society further. Many socially vulnerable Indians in chains died on ships enroute to their destinations under harsh conditions. Even though this practice of slavery may have

continued up to the mid-19th century, it is surprisingly ignored in popular Indian history today. These enslaved should be distinguished from the large number of indentured (bonded) Indian labourers of the later colonial periods, who may have been subjected to slightly less cruel conditions in their transport and work in the far-off lands. Unlike Africa and Asia, indigenous population in the Americas and other sparsely inhabited northern and southern most areas of the planet, faced the worst consequence of these newfound ideas. The remains of the earlier Olmec and Maya civilizations, and the later Inca and Aztec civilizations of the Americas have elicited recent academic interest, in addition to the other ancient settlements in the Amazon, but the destruction of ancient texts of the Incas and Aztecs in the Spanish invasions makes this task cumbersome. Sadly, even today, the idea of stifling the erstwhile colonized societies using economic subversion and a divide-and-rule social approach, continues as a Machiavellian geopolitical tool aptly called neo-colonialism. Africa in particular, may have to rediscover its old roots of the iron age and beyond, if it has to move ahead from its colonial past.

On the brighter side, the increased volumes of trade possible through the sea, sometimes allowed a faster conquest of older ideas by the apparently more useful ones. By the 12th century, trade had already introduced the Indian numeral system, arithmetic and algebra into Europe through translation (such as *Algoritmi de Numero Indorum)* of the two books written in Arabic by Al Khwarizmi in the 9th century: *kitāb al-ḥisāb al-hindī* (Hindu arithmetic) and *Al-Jabr* (Restoration). As indicated in the preface of the second book, Al Khwarizmi had been nominated by the ruler of Baghdad as a leading translator of Sanskrit and Greek texts to write popular local versions of the known, which may have included a major reworked version of Ptolemy's *Geography*. The extinction of texts in the ancient library of Alexandria in Egypt and others in Greece, and the sudden total destruction of the library of Baghdad (i.e. House of Wisdom where Al Khwarizmi had worked) by the Mongol forces, just as the ancient Indian universities of Takshashila and Nalanda by invaders at different points of time, has left a large hole in our history of ideas. The actual progression and exchange of ideas among civilizations may not be fully evident to us today. By the 16th century, Indian numerals started replacing the Roman numerals entirely at the beginning of a great scientific renaissance in Europe, with new words coined and used today such as 'Algebra', 'Algorithms' and 'Hindu-Arabic' numerals crediting the two popular books of Al Khwarizmi (who was not Arabic but Persian in origin!).

Meanwhile, Copernicus first and Galileo later, may have seeded the scientific revolution in Europe by their efforts to propose a heliocentric view of the universe where earth moves around the sun, thus contradicting the bible. While Copernicus may have been careful to publish his work only as a hypothesis to explain the observations just a few years before his death, he nevertheless had to endure serious ridicule. Galileo on the other hand had to suffer persecution until his death in 1642 and both their texts were prohibited for more than a century later, and the earth centric view of the universe was finally abandoned by the Catholic Church in the early 1800s. Danish astronomer Tycho Brahe's observatory off the coast of Sweden and German astronomer mathematician Kepler's improvements of Galileo's telescopes may have played a key role in these developments of the 17th century, and may also have motivated Newton's later works in optics. All this was possible in time as the Chinese movable-printing had been further mechanised by Gutenberg in Germany, and these printing machines had spread along with the *Gutenberg bible* throughout Europe. This aided an unprecedented speed in spread of knowledge that was not possible earlier. The hunger for exploiting natural resources in the new lands by the colonial enterprise also funded and launched modern

science. It was one such voyage on the survey expedition of HMS Beagle as a geologist, that allowed Charles Darwin to do his studies on the evolution of animals. The newfound resources and modern warfare also enabled widespread adoption of the steam engine in shipping, locomotion and production of goods, thus taking us into the industrial revolution. As trade and economics became global, the ideas could now move faster, but the movement of goods and people was still under subjugating conditions.

Industrial revolution, nation-states, and the emergence of professional science (beginning about 250 yrs ago): Our imminent challenges

By the late 18th century most ports of the world and the global trade were under the military control of the European powers along with a fast-expanding network of colonial plantations populated by slaves working tirelessly, and a booming arms trade. Colonial subjects were already subjected to stringent taxes and a lack of independent access to the world outside. Thus, a large relative growth of Europe's living standards compared to the rest of the world began well before the industrial revolution in production of goods. This is today known as the *great divergence* when Europe's average income quickly increased to more than ten times that of the rest of the world despite the two world-wide wars fought by its colonial empires that killed about 100 million people! This toll was in addition to the millions who died in the cholera epidemics of the 19th century, and the 50 million who died in the Spanish flu pandemic in the early 20th century. From an exporter of cotton fabrics, India would be forced to become an importer of fabrics and a supplier of raw cotton for the British mills, resulting in famines and a loss of biodiversity in food crops. The famines due to the colonial policies, including the ones during the world-wide wars, would later reflect genetically in Indians having the highest incidence of diabetes today. India's GDP as a fraction of the world's would reduce from 25% to 2% by the end of British rule, while Indian soldiers fought on the side of Britain all through. This economic divergence of Europe and its settler countries compared to the rest, became very sharp in the early 19th century due to a significant invention of humans that would help the inflow of colonial wealth and its allied production activities.

The improvement of the external combustion steam engine in the late 18th century by James Watts among others, may be considered as the beginning of a new revolution in locomotion and production of goods. Efficiency of steam engines at 10% in converting chemical energy to mechanical work was now comparable to that of the biological systems of humans and animals at 25%, but the former could also be scaled up to do very large workloads that would not be possible otherwise. Cheap agrarian supplies moved from colonies would free local labour and provide raw materials for the future industrial revolution in Europe when the shallow coal reserves in Britain and elsewhere could supply fuel. Even the hinterlands across the world far away from the ports became more attractive in the colonial enterprise as the raw materials and finished goods could now be moved easily to and from the ports, thus bringing most of the human world under its direct or indirect control. While Darwin was still on the survey expedition in the 1830s to find new resources, some of the first steam ships with screw propellors set into the oceans making long journeys viable for both novices and agricultural products beyond the spices and cotton, even as the first rail line became operational in England. Later Faraday would experiment on electromagnetic effects that would help us use electric motors further into the future. The discovery of electricity and electromagnetism was a sub-revolution that gave its own series of advantages to humans, which

would then become widely usable only after the transmission lines developed in the early 20th century. The light bulb invented by Edison then allowed humans to free themselves of the diurnal cycle of days and nights in daily lives, just as telegraphy made instant long-distance communication possible for the first time, even if it was across an ocean. By then the smaller and more efficient internal combustion engine developed earlier by Nicolaus Otto, following the experimentation by several others over a century, would also be ready to power personal cars and flying planes.

The industrial revolution of the 19th century had made discoveries and inventions relevant for immediate practical use, thus coupling science and economics and beginning a *trademarked* science for the first time since ages. Science until then, was typically an individual's pursuit of the truth and its record for posterity which rarely had immediate public use or guaranteed personal recognition. Great personal efforts driven by curiosity were required for discoveries and inventions, as they did have vagaries in monetary support and the means to do science. While Syphilis was called as the French disease by the Italians, and the Italian disease by the French, Fracastoro correctly postulated the germ theory of disease in *de Contagione* in 1546. The Dutch textile merchant van Leeuwenhoek may have used his newly developed microscope in 1677 to identify these little animals that caused diseases. A hundred years later in 1796, Edward Jenner suggested inoculation for smallpox in Europe followed by more careful demonstrations (which had been in use in Africa, India and China, and later moved to Turkey and elsewhere in the 15th century) while Mary Montagu, and Benjamin Jesty had already suggested inoculation earlier in that century. Jenner was luckier than most and was handsomely rewarded with a princely sum of ten thousand pounds by the British parliament in 1802 and another twenty thousand pounds five years later. The bigger breakthrough came from Louis Pasteur in 1885, who despite enduring a stroke and motivated by the tragic death of two of his daughters to typhoid, created the first laboratory-produced vaccine for fowl cholera in chickens, and successfully prevents rabies through post-exposure vaccination. Around the same time, immunization against cholera bacteria was introduced by Clua in Spain, while Pacini in Italy may have isolated the bacteria a few decades earlier. A decade later, Marie curie, a Polish immigrant and a brilliant scientist, melted seven tonnes of pitch (Uranium ore) in a French shed for a few grams of the radioactive element radium with persistence and physical toil for four years. Her earlier work with husband Pierre Curie on radioactivity in general, and this later work on radium, both were awarded with Nobel prizes in two different disciplines, a unique feat that was not repeated hence.

This *amateur* science until the early 20th century, trademarked and meagrely supported but neither professional nor broadly accessible yet, produced some of the greatest human discoveries in the recent ages including the great strides in modern mathematics and the foundations of modern physics even before professional science took over. This was more so in the colonies like India which may have contributed disproportionately more during those difficult times. India as an impoverished colony with a few educational institutions mostly in the erstwhile capital Kolkata and negligible funding for research could continue to produce notable scientific contributions from individuals, but note that it has not been able to do equally so for nearly a hundred years hence. Modern professional science where the collective of the scientific network dominates over an isolated individual has its own advantages in securing jobs and talent broadly, and the fast development of basic science into technology. But it can fray the relationship of the individual scientist with the truth, when provenance and peer-certification become important in such an organized competitive professional network.† Science reminds us that *what is being said* is far more

important than *who is saying it*, and only ideas with the least logical self-contradictions, and least violations of the principles of natural laws would survive into the future. Some of the inefficiencies introduced by professionalization of science like inflation of papers published; lexicalization, duplication and over-specialization of scientific training; a futile proliferation of professional organizations and their accolades; are all expected to be exposed and rectified by (collectives/societies of) Artificial Intelligence / Artificial Integrity (AI) agents, provided the latter paradigm is used wisely.

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† The coupling of religion with economics and politics in the city-states and early empires, especially in the form of monotheism may have parallels in science. The increasing coupling of science with economics makes its coupling with politics inevitable, and the potential similarities in long-term consequences on science are hard to fathom currently.

†† Our speculative investment in markets (financial economy) is worth 2 years of our products (GDP), and 8 working-life-years of savings, and we are yet to find an efficient and robust way of investing our efforts into the future.

As humans organize themselves into more complex collectives which may be based on physical proximity as is the case in a city or a country, or as a complex global network of interdependence as in professional science, economic supply chains, or monetized social media, we have to acknowledge the three basic challenges in achieving collective outcomes driven by individual needs. Surmounting these three challenges determines whether the individual intelligence of humans provides us collective brilliance or not. The first challenge is to be able to measure the collective outcomes and the corresponding inputs of individuals using some metric (*measurement problem*), and the second is the ability to collectively set prudent goals (*social/political problem*), and the third is to achieve the targeted collective outcomes using the above measurements and by incentivising the required individual inputs (*policy problem*). Even the indispensable first challenge is enormous enough in white-collar tasks where the actions and their consequences can be separated by quite a distance in space and time. For example, we do not have even a notionally reliable system of measuring scientific contributions of individuals in a timely manner, and any metric invested in for such measurements becomes quickly unusable in a decade or so as brilliant scientists can simply focus on maximizing their own valuations in the given metric in a manner that violates its basic assumptions. In economics, these three challenges are cumulatively taken care of by a temporary collapse of the system i.e. boom-and-bust cycles when individuals learn bitterly, policies and governments change, and thus any inefficiency is supposed to have been penalised. This crude method of managing collective goals and individual needs by infrequent collective punishment has its limits as the economic networks with a colonial legacy became more complex, and the inefficiency of individuals can be cleverly hidden under the challenging measurement problem.†† Unfortunately, this futile economic approach has been translated (and connected) to other systems ranging from professional science and health systems to social media and may lead to large scale imminent problems for humans that even the best expert would not predict.

This measurement problem highlights the role of moral and ethical values ingrained in individuals of the society. Plato's *Republic* related the preferred values of a society to the corresponding forms of rulers in a decreasing order of preference: *Knowledge* – wise philosopher kings; *Honor* – good soldiers; *Money* - oligarchs; *Freedom* - Democracy; *Power* - Tyrant. Recall that the agricultural revolution and the urbanization in the bronze-age, followed by the second urbanization into city-states were primarily driven by (1) the basic physiological and health needs,

followed by (2) the security needs of an individual. This also provided the average human to pursue the higher levels of human needs categorized by (3) social validation and status, and (4) purposeful fulfilment of one's abilities. *Note that the first two needs can also be pursued as a collective goal of the society, while the latter two cannot be*. Ideally one may like to have a politico-economic system that is heavily involved in the first two but not the latter two individual needs of humans. This may be the rationale of communism which has the great practical disadvantage of limiting its leadership to the most power-hungry. Capitalism on the other hand tightly ties the individual's need for social status with the first two basic human needs in a competitive framework, leading to contradictions between the progress of an individual and that of the society. These two dominant politico-economic ideologies in their extremes, may have caused tens of millions of direct deaths, in addition to more indirect deaths of humans just over a century. The best one can hope for today is a democracy where its politics does not foster insecurity and a scramble for power which is best exploited by the tyrant. Unfortunately, the illiberal spaces of the world subject to tyranny are all hidden in plain sight, while liberalism in politics is limited to competitive virtue-signalling at the most liberal parts of the world.

The *third urbanization* we are currently into is primarily driven by the need (3) of individuals and hence sets us up for a serious conflict with the progress we have collectively achieved in ensuring needs (1) and (2) so far. How do we know we are into the third urbanization over the last hundred years? The average lifetime use of materials by a single human being currently is around 350 tonnes of concrete, 80 tonnes of coal, 40 tonnes of liquid fuel, 20 tonnes of steel, 7 tonnes of plastic, 5 tonnes of paper, and 2 tonnes of clothes. This is fast increasing and beginning to dwarf the dietary needs of humans at 14 tonnes of grains, 10 tonnes of veggies and 2 tonnes of cooking oil used. It has threatened the ecological sustainability and biodiversity of the planet, including the nutritional security of humans. The loss of diversity in food crops is alarming, for example, the four thousand varieties of potatoes in the United States may have been reduced to only half-a-dozen today. The unknown origins of the Covid-19 pandemic and its long-term health consequences also point to the same fallacy. Unlike physical health, the emerging problems in mental health are hardly apparent to the individuals themselves, and they may be due to the rapid increase in transactional human interactions, and so are the unknowns in the continuous long-term exposure to man-made electromagnetic radiation. These issues may couple negatively with the oncoming collapse of white-collar jobs due to AI, which the blue-collar workforce as well had experienced a generation earlier. An implicit model of ruthless competition in geopolitics i.e. only the fittest survive to write their history, also contradicts the sophisticated Nature around us that is filled with examples of cooperation and symbiosis driving its evolution.

While the significant historical events may seem relatively sudden to us, they are corrections to the logical contradictions accumulated over time by our defective ideas, further precipitated by the natural climatic shifts. These cyclical crises in economics and geopolitics are accompanied by large shifts in technology used and introduction of new diseases, with the larger more impactful changes every five hundred years or so. They undoubtedly result in a tragic avoidable loss of human lives representing a significant fraction (5-10%) of our population. The strong human imprints on the planet's ecology now can hasten these historical cycles in human civilizations, and we may be at the cusp of another five-hundred-year shift. Our problems largely were, and are, of the human mind and its goals, and these cannot be solved by technology alone. A wider understanding of both our political and non-political history may be an antidote to such a punishing crisis this time.